JOURNAL

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AIR POLLUTION CONTROL ASSOCIATION

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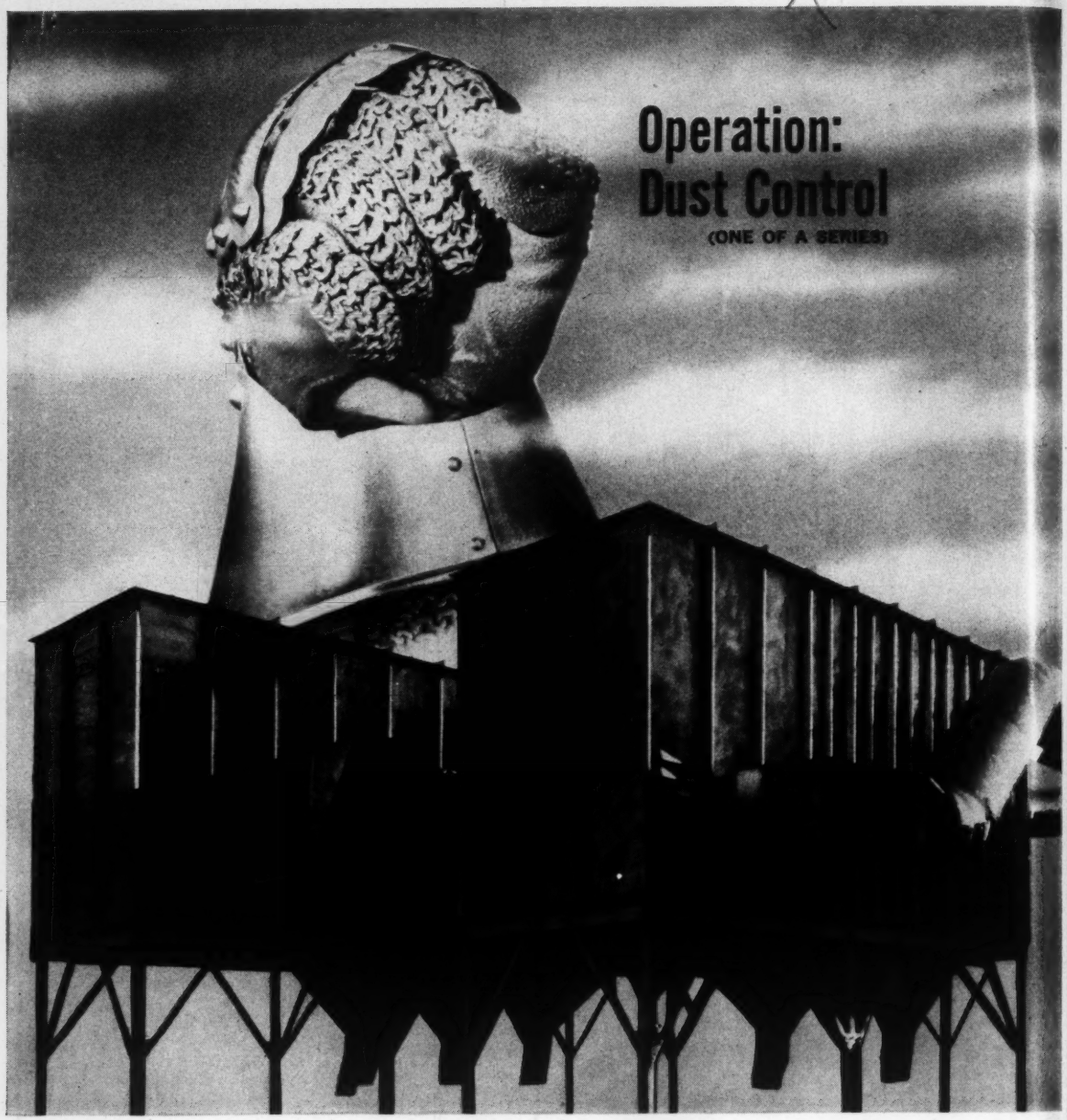
SCIENCE & TECHNOLOGY

Dr. W. L. Faith, APCA's New President. (See page 300.)



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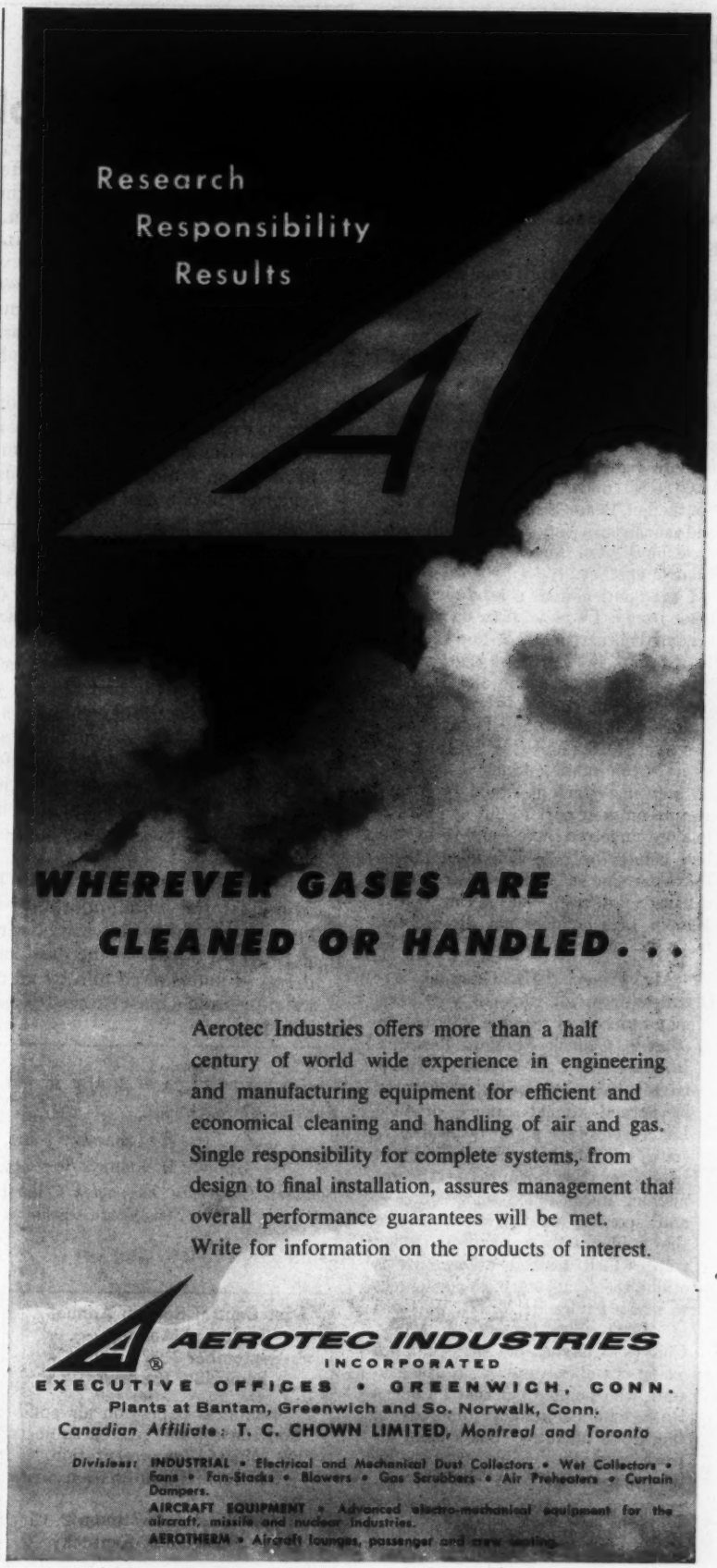
(*Continued on p. 303*)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LETTERS to the EDITOR

No More Folklore

Editor:

A letter in your April issue from Mr. Erwin K. Kauper, pleads with you "for the sake of the poor, befuddled public" not to try to start a new smog "folk story" with all kinds of "facts" being circulated by all types of "experts."

I agree with him wholeheartedly and suggest he begin his campaign against folklore right there at the address he has listed under his signature—434 South San Pedro Street, which by an odd coincidence happens to be the address of the Los Angeles Air Pollution Control District.

I am quoting from a tape recording made from a TV panel show on Sunday evening February 5 at 7 PM on Channel 11, Station KTTV, Los Angeles. It was a smog panel show and I asked Mr. S. Smith Griswold (whose business address is 434 South San Pedro Street, Los Angeles) the following $64 question as a curtain-raiser: (Since I received no answer I think it would be a fine gesture on your part to put at rest the folklore involved here—nip it in the bud before the poor befuddled public is taken for a billion-dollar "auto exhaust device sleigh-ride"—Mr. Kauper says he does not dispute the fact "that autos cause smog.")

> Mr. Fisher: "Mr. Griswold, scientists from all three of your own major sources of research information (that is, Caltech, Stanford Research Institute, and U. S. Bureau of Mines) have specifically testified that autos in normal tuning cannot produce Los Angeles-type photochemical toxic smog, why do you nevertheless persist in referring to autos as the remaining uncontrolled smog source—and sponsor state laws to saddle the public with a phantom 'smog trap' which Detroit advises us is still in the dream stage. Your sources to which I refer are Mr. R. W. Hurd of Bartlesville, Bureau of Mines, Charles Chayne of the Stanford 'smog chamber,' and A. J. Haagensmit, who pointed out that Pasadena Rose Parades attract hundreds of thousands of autos—but seldom attract even the visible symbols we refer to as smog."

Having the same address as Griswold, perhaps you can answer the question in his stead—and stamp out this vicious tendency toward "folk stories in our smog information diet."

Very sincerely yours,
GEORGE H. FISHER, *Secretary*
Southern California Taxpayers Council for Simplified Government

East Central Section Annual Technical Meeting—September 21, 22, 1961, Louisville, Kentucky

Technical papers on air pollution control and related subjects are solicited for presentation.

For further information write to Ralph W. Bourne, Room 2, City Hall, Louisville 2, Kentucky

Secretary's Page

Accomplishments

Your Association has many different bases for evaluating its accomplishments. The fiscal year begins on May 1 and ends on April 30. The contract year with the Mellon Institute begins on September 1 and ends on August 30. The JOURNAL is now published on a calendar year basis, with number 1 of the new volume beginning on January 1 and number 12 ending the year in December. The abstracts volume year begins in June and ends with number 12 being published in May. However, the new year that means more to the membership and the administration of APCA's affairs begins immediately after the annual meeting.

Before starting the new year under Dr. W. L. Faith's administration, it would be well to reflect the accomplishments of Harry A. Belyea and his administration. Most important, was the publication of the JOURNAL on a monthly basis in January 1961. This represented the achievement of a goal set out for APCA 10 years before, and brought us into the "big league" in technical publications. The by-law amendment for increase in dues was achieved, and the increased revenue more than offset the increased publication costs of the JOURNAL. As a matter of fact, in spite of a year of poor business conditions, APCA's financial position finished in the black for the fiscal year.

The Technical Council was re-organized, with many new committees activated in important fields of interest. All committees were revitalized so that, for the first time in years, the membership directory reflected an active list of committees and committee members instead of a list of names. These committees are the backbone of the organization, for without the volunteer efforts of APCA's membership, there is no recruitment for new members, no flow of technical reports, no annual meeting. The professional staff in Pittsburgh do a great deal of mechanical work, but nothing can be accomplished without our volunteer committees.

Membership, under Dr. Faith, has set a record in its increase to well over 2000, but more important—there is now a sustained, continuing membership drive that will be carried on into the new administration.

Harry A. Belyea, as the President of APCA this past year, has a well-deserved kudos owed him by all members. Our thanks go to him for his efforts and a most successful year.

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A Monthly Journal
Devoted to
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Editor: Arnold Arch
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The Editor welcomes writers interested in air pollution problems and encourages them to use the pages of this journal for the expression of their opinions, but neither he nor the Association assumes responsibility for the validity of the opinions expressed herein.

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RATING *of* DUST COLLECTORS *According to* DUST SETTLING VELOCITIES*

WESLEY C. L. HEMEON, Director, Hemeon Associates, Pittsburgh, Pa.,
GEORGE F. HAINES, JR., Formerly Hemeon Associates; Presently, Bethlehem Steel Co., Bethlehem, Pa., and
SAMUEL D. PUNTURERI, Goodyear Atomic Corp., Portsmouth, Ohio

The importance of size characteristics of dust on the performance of dust collectors of various types is generally accepted, but techniques entirely satisfactory for the application of this principle to the appraisal of dust collector performance as well as for their design have not heretofore been available.

Fractional Efficiency Rating

The first progressive step in this direction was taken a number of years ago by a dust collector manufacturer when it instituted a performance rating system on the basis of particle sizes. A table or graph describes the efficiency of dust collection for a series of particle sizes, data for which are obtained by elutriation in the laboratory of dust collected from the field. A number of other manufacturers adopted this rating method subsequently. Various methods of elutriation have been employed, most of them involving dispersion of dust in a small air stream and passage of the dusty air through a series of chambers, each calculated to drop out particles of different settling velocities. Elutriation in water suspensions of the dust has also been used.

Even though this development was a step in the right direction, it was always less than perfect, as to which all will testify on the basis of numerous experiences where prediction of performance based on such size measurements often failed to match the facts of subsequent performance.

In the past few years a group of dust collector manufacturers has joined in a program of investigation centering around experimentation with one particular type of elutriator in an attempt to develop some basis for standardization of techniques for the determination of particle size characteristics.

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Holtel, May 22–26, 1960, Cincinnati, Ohio.

Basic Defects in Current Techniques

All evaluation methods heretofore and presently used, regardless of variations between them, have one common characteristic which is also a basic defect. This is in the fact that samples of dust are collected from an operation by some sampling means and transported in their condensed form to the test laboratory for redispersion into an air stream. The sampling process of course permanently destroys the original state of dispersion. One can only hope that the redispersion process in the test laboratory recreates the conditions originally prevailing. There is of course no certainty at all that this is realized. In fact, it is highly unlikely, especially as to the smaller particles in the mixture, that this objective is attained. In any case it is obvious that one is operating completely in the dark on this score.

Problems in Redispersion of a Dust Sample

We have previously discussed this matter[1] and illustrated it diagrammatically as shown in Fig. 1. The diagram illustrates commonly-occurring situations and the relationship between aggregation, condensation, and redispersion. It indicates the difficulty, if not impossibility, of obtaining reliable information on the dust particle characteristics (settling velocity) that truly determines its behavior in many types of dust collectors.

In that earlier paper, we discussed this matter as follows:

"A fourth situation (d) pertains to the size analysis by air elutriation in the laboratory. This involves collection of the sample from the original gas (air) suspension, transport to the laboratory, and redispersion into a stream of air carrying it through a gravity elutriator. The figure illustrates the case where the laboratory elutriator fails to break up the aggregates formed by the condensation process which is the essence of the initial sampling.

"These line-drawing illustrations are obviously a considerable over-simplification of the nature of particle aggregation. There must actually be combinations of various types of aggregation in actual practice. In some instances, the result of a particle size analysis will correspond to its inertial properties as defined by its behavior in a dust collector or air filter. It is safe to say, however, that for the most part this would be coincidence except where the particle mixture is completely dominated by weight of large particles, since aggregation is of little significance where the particles are all large. This is illustrated by the lack of coherence in dry grains of sand in contrast with that noted in a mass of fine powder.

"There can be little question that the prevalent confusion in the rating of dust collector performance is due largely to failure of particle size measurements properly to indicate the inertial characteristics of a dust mixture mainly for the reasons indicated in the preceding discussion."

Direct Measurement of Settling Velocity

We have long been interested in the possibility of developing means to measure directly the "distribution of settling velocities" in a dust mixture. Hatch and Hemeon[2] discussed this problem in the consideration of the behavior of dust particles on passage through the human respiratory system in the process of inhalation, and described an air-sampling apparatus which includes a glass spiral at the entrance to an air sampler. The spiral, simulating qualitatively the nasal and other respiratory passages, removes particles from the air stream according to their inertia regardless of their state of aggregation. In this paper we also demonstrated the fact that aggregation of dust particles

in air suspension is a common occurrence.

Various types of dust collectors of the mechanical type (cyclones, scrubbers, etc.), like the human respiratory system, remove dust particles from a gas stream according to the inertial characteristics of the dust mixture, characteristics which can be conveniently described in terms of the "distribution of settling velocities." This term, it will be noted, is analogous to the phrase "distribution of particle sizes." We emphasize once again that it is settling velocity which determines behavior of dust particles in such devices, not particle size.

In this connection we draw attention to a paper by Foley[3] in which he emphasized the importance of citing dust settling velocities, but it should be noted that he was referring to quite a different aspect of the subject than we are discussing here. He made the point that particle size as determined by screen analysis or by microscopic determination was in fact an erroneous and hazardous basis for describing the size characteristics of dust particles as to their behavior in dust collectors. He was not concerned, as are we, with the defects of the liquid and gas elutriation devices employed for getting data on settling velocity characteristics.

For a number of years, we sought a basis for measurement of those dust characteristics which will truly characterize the inertial properties of dust as they exist in a gas stream, a technique whereby the raw dust-laden stack gases would be drawn through a device and the particles in their original state of dispersion classified therein according to their settling velocities. Realization of this objective would then provide a technique for the development of a realistic basis to describe the performance of dust collectors according to their ability to remove dust particles of differing settling velocities. This would apply to those collectors whose action depends on dust particle inertia, i.e., various types of water scrubbers, cyclones, and other types of mechanical collectors wherein the impaction process is the dominant characteristic.

Research Program

Several years ago a program of research, sponsored by the American Iron and Steel Institute in the Industrial Hygiene Foundation at Mellon Institute, provided us with the opportunity to delve into this matter and for some time resulted in a frustrating sequence of unsuccessful developments. None of the earlier devices met our specifications satisfactorily, i.e. (*1*) that the results of a test be self-defining; that is to say, it should not be necessary to describe the instrument performance by reference to a calibration employing another parameter such as microscopically-determined particle size; (*2*) that it be portable, rugged, and readily operable under any conditions encountered in the field on hot, raw stack gases.

We were finally successful in developing a rather simple apparatus meeting these specifications.

The Stack Site Dust Elutriator

The elutriator is illustrated diagrammatically in Fig. 2 which shows a number of trays disposed horizontally, through the spaces of which the dusty air is drawn, thence to a filter, flowmeter, and air pump. The purpose of multiple channels is simply to attain a condition of streamline motion by a reduction of the diameter factor in the Reynolds number. Because the gas stream is in streamline motion, dust particles settle to the floor at locations determined by their settling velocity, the settling velocity of the gas stream, and the vertical position at which they entered the channel.

At the end of a run, weights of dust settled out in various segments along the length of a channel are determined along with that collected in the after filter.

Plotting of the data, with cumulative weight percent of sediment as ordinates and corresponding length across the channel as abscissa, results in a curve of the sort shown in Fig. 3, which, however, has been cropped and the lower left section magnified for clarity. The total graph would extend to 30 in. along the abscissa and to 100%

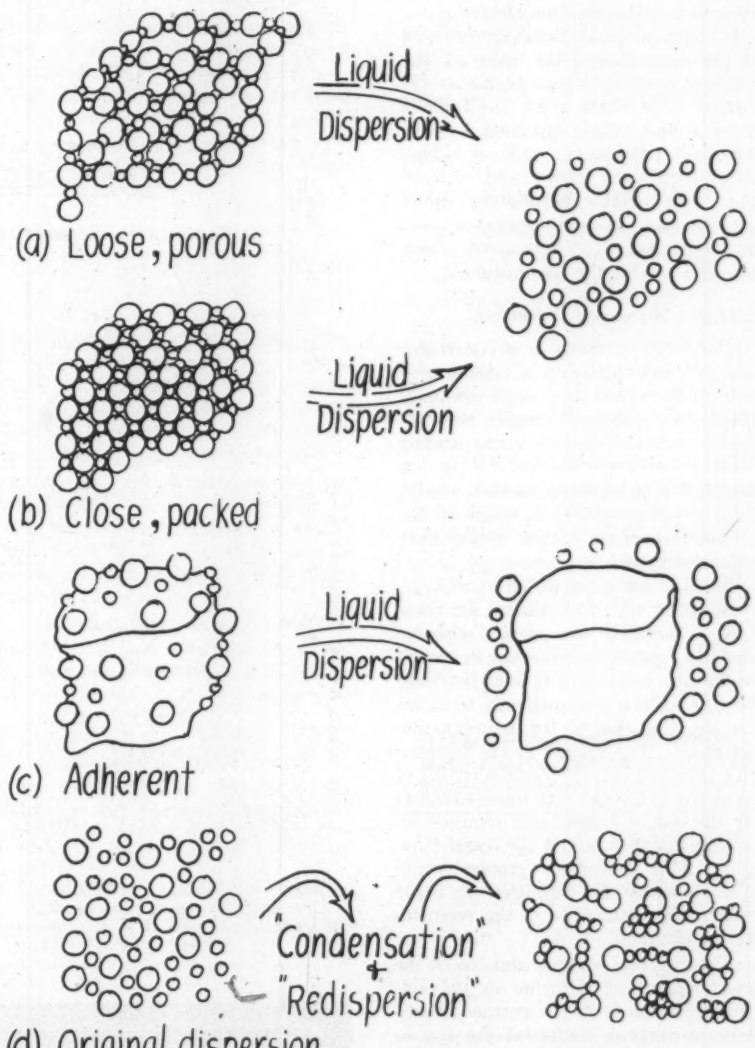

Fig. 1. (a), (b), and (c): Various forms of particle aggregation indicated at the left; and at right, the breakup of aggregates due to dispersion in liquid during preparation for size analysis. (d) Represents the air elutriator sizing method in which particles originally well dispersed are imperfectly redispersed.

on the ordinate.

The slope of the curve at any point corresponding to some particular value of L describes the weight of all particles having a settling velocity greater than a particular value. That value is the velocity of a particle which entered the channel at its topmost boundary. It is calculated by a simple proportion:

$$\frac{u_t}{h} = \frac{V}{L}$$

where u_t is terminal velocity of the dust particle; h is the vertical height of the channel; V is the linear gas velocity through the channel; and L the distance from entrance selected for the analysis.

It follows therefore that if we strike a tangent to the ordinate at any point, its intercept will indicate the cumulative weight percent of dust particles having a velocity greater than that calculated according to the equation above.

It might be thought that the drawing of the tangent and the value of the resulting intercept would be rather uncertain. The data given in Table I describe the values obtained by five different individuals, each of whom drew their own curve and derived their own weight distribution values without any previous experience with the technique. The agreement is surprisingly good in the circumstances.

Elutriator Shape and Dimensions

The term elutriator is a convenient one although probably a misnomer if one considers that term applicable only to devices which physically separate dust particles into groups corresponding to their settling velocities. With our device, it is to be noted, no such separation occurs except as a result of the graphical analysis of the weight data produced by it.

One of the most serious problems, solution to which eluded us for some time, concerned the means whereby the dusty gas stream traveling in a stack or flue at a velocity of 40 to 60 fps could be transformed systematically to about $^1/_2$ fps, that desired for sedimentation purposes. The process of gas deceleration is in fact one of turbulent mixing of elements of the gas with other elements of the same stream and requires an appreciable distance for the transformation. This turbulent process could not obviously be permitted to occur within the boundaries of the sedimentation channels.

The eventual solution and one of the most important elements in the elutriator design is in the entrance vestibule, a vertical section at the top of which the high velocity gases enter and whose length is sufficient to complete the turbulent transformation of velocities while avoiding premature sedi-

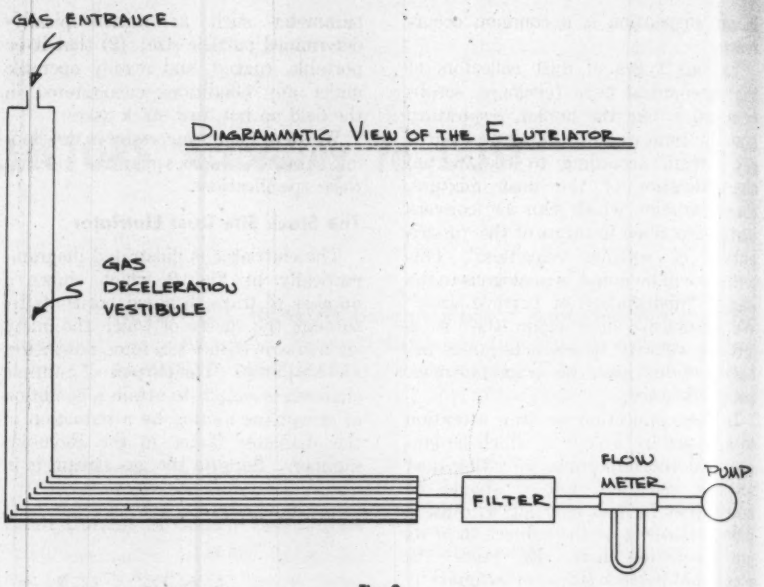

Fig. 2.

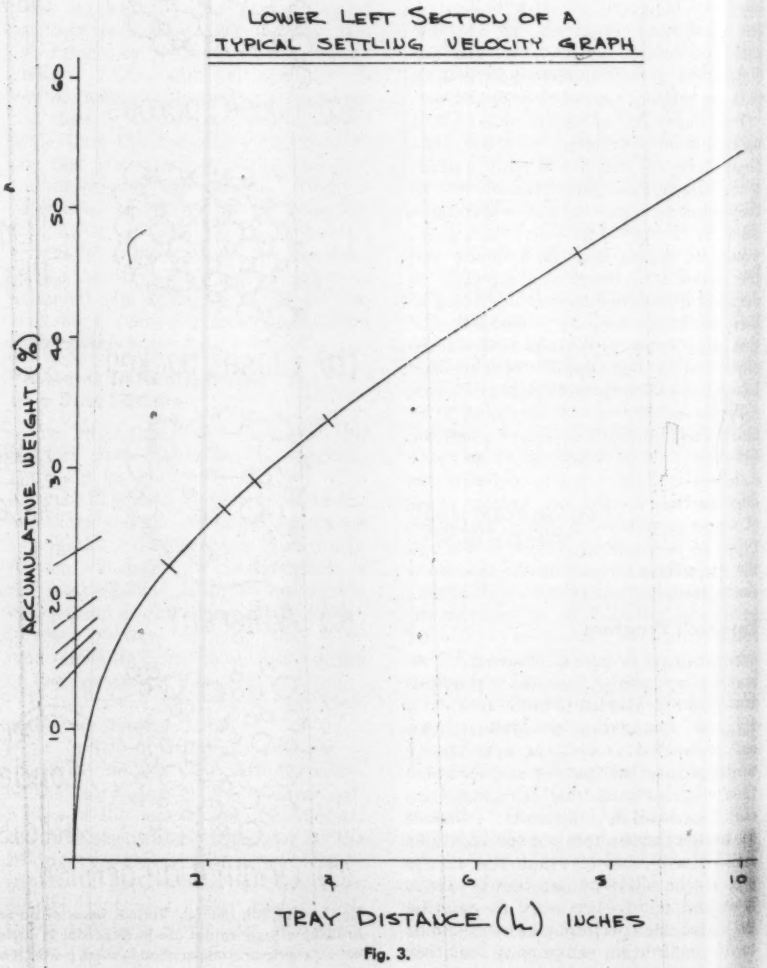

Fig. 3.

Table I—Comparison of Graphical Analysis of the Same Data by Five Individuals Independently

	Rh	Schr	Sh	Dr	GFH
	(a) Cumulative Weight Percent				
>20 fpm	14.5	15.0	14.5	14.0	14.5
>10	16.0	16.5	16.5	16.5	16.0
>7	20.0	17.8	17.5	18.0	17.0
>4	22.5	20.0	19.7	19.5	18.5
>2	25.0	26.3	26.0	26.5	24.5
<1/2	55.0	55.7	62.0	59.5	54.5
	(b) Weight Percent of Dust in Different Settling Velocity Fractions				
>20 fpm	14.5	15.0	14.5	14.0	14.5
10–20	1.5	1.5	2.0	2.5	1.5
7–10	4.0	1.3	1.0	1.5	1.0
4–7	2.5	2.2	2.2	1.5	1.5
2–4	2.5	6.3	6.3	7.0	6.0
1/2–2	30.0	29.4	36.0	33.0	30.0
<1/2	45.0	44.3	38.0	40.5	45.5

mentation of dust particles. This vertical section is joined at the bottom with the horizontally disposed elutriator section which is four inches square in cross section and 36 inches long. This horizontal section contains eight trays which break up the cross section into eight channels, 1/2 in. in height.

The connection between the vertical and horizontal sections is in effect a mitre elbow and requires the gas to make a 90-degree turn. Contrary to expectation, this turn does not result in perceptible turbulence.

The gas flow capacity of this particular unit is 3.3 cfm which results in linear velocities through the channels, of a little over 1/2 fps. These dimensions result in a Reynolds number well within the streamline region. Visual evidence of the streamline condition is seen following a period of dust sedimentation when a dust-free shadow is apparent the entire length of the tray downstream from any obstruction. Figure 4 is a photograph of one plate, the shadow on which is faintly apparent.

Application to Rating of Dust Collector Efficiency

Data of the type set forth in any of the columns in the lower portion of Table I typify results that are obtained by the application of this technique. It can readily be seen that the simultaneous analyses preceding and following a dust collector on a dust of previously undefined and unknown characteristics provide the basis for a description of the ability of the dust collector to remove dust particles of various settling velocities. Such a test on a multiple cyclone type dust collector is given for illustration in Table II.

It is interesting to note the significance of the fact mentioned above, i.e., that the particle size quality of the dust employed need not be defined in order to derive a fractional efficiency description of a collector. Results as to fractional efficiency would be the same even though one employed a whole series of dusts of different characteristics, except to the extent that some other characteristic of the dust might affect the results.

Summary

We have described the apparatus and a technique which makes it possible for the first time to measure the inertial quality of any dust for determination of its collectibility in various types of equipment where inertial forces predominate. It measures the distribution of settling velocities (analogous to the phrase "distribution of particle size") which might be described alternatively as the distribution of particle inertia; and because of the significance of these qualities can be said to measure the collectibility of the elements of a dust mixture.

It is self-defining in the sense that calibration is not necessary by means of some other technique, e.g., microscopic. Moreover, it is a simple device and readily portable.

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1. W. C. L. Hemeon, "Dust Particle Inertia and Various Consequences," *ASHRAE Journal Section, Heat., Pip. and Air Cond.*, 247–50 (February 1957).
2. Theodore Hatch and W. C. L. Hemeon, "Influence of Particle Size in Dust Exposure," *J. Ind. Hyg. & Toxicol.*, **30**: 3, 172–180 (May 1948).

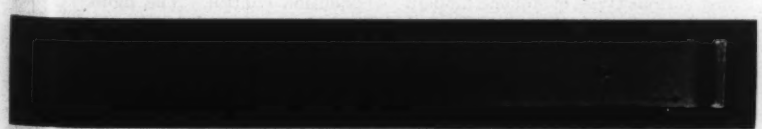

Fig. 4. Longitudinal dust shadows signify freedom from turbulence during sedimentation.

APPLICATION SUBMITTED BY OXY-CATALYST, INC. FOR CATALYTIC MUFFLER

Oxy-Catalyst, Inc. of Berwyn, Pennsylvania submitted application to The California Motor Vehicle Pollution Control Board for certification of its long-tested catalytic muffler for reducing air pollutants from auto exhausts, announced Gordon P. Larson, executive vice-president.

This is, it is authoritatively believed, the first and only submittal to this time embodying years of extensive testing in Detroit in collaboration with The Automobile Manufacturers' Association and one of its members, a licensee of Oxy-Catalyst, Inc.

Headed by scientist E. J. Houdry, chairman of the company's board and winner of the coveted Perkins Award for distinguished service to chemistry, Oxy-Catalyst, Inc. is the world's only manufacturer of exhaust controls for indoor vehicles and has been engaged for the past 12 years in a pioneering study and production of fume elimination devices.

Accomplishments Cited

"In submitting our application, we wish to publicly acknowledge the precedental accomplishments achieved so far, under pressures of time, in the program for auto exhaust pollution reduction by Governor Edmond G. Brown, Assemblyman Ronald Brooks Cameron, sponsor of the governing law, chairman John Middleton of the Motor Vehicle Pollution Control Board and colleague Board members, and Donald Jensen, executive officer of The Board and his staff," Mr. Larson said.

"The Houdry muffler is the constantly improving product of more than four years of applied experimentation and continual testing with The Automobile Manufacturers' Association and with one of its members, a licensee of Oxy-Catalyst, Inc."

Table II—Fractional Efficiency According to Settling Velocity of Multiple Cyclone Dust Collector

Settling Velocity	% Collection Efficiency, by Wt
>20 fpm	99.5
10–20	98.6
7–10	98.1
4–7	97.0
2–4	93.7
1/2–2	84.1
<1/2	29.2

3. R. B. Foley, "Terminal Velocity as the Measure of Dust-Particle Characteristics," *Trans. of A.S.M.E.*, 101–108 (February 1947).

AIR POLLUTION CONTROL *as Seen by the* ELECTRIC LIGHT *and* POWER INDUSTRY*

GEORGE T. MINASIAN, Director of Community Relations, Consolidated Edison Company of New York, Inc., New York, N.Y.

At the end of 1959, the electric light and power industry had an installed capacity of nearly 160,000,000 kw. Three-quarters of this capacity represents investor-owned companies, the remainder, federal, state, municipal, and co-op plants.

Setting aside the 20% of total capacity represented by hydro stations, we have left about 125,000,000 kw of steam-electric power plants which burn primarily coal, oil, or gas as fuel.

Incidentally, the United States has more than three times the power capacity of Russia, which stands second. By 1965 the Russians expect to more than double their capacity to 113,000,000 kw. But by then the United States will have 250,000,000 kw in operation.

In 1959, the steam-electric light and power industry consumed the following amounts of fuel (source: Federal Power Commission preliminary figures):

168.43 million tons of coal representing approximately two-thirds of the kilowatthour output
88.35 million barrels of oil
1627.08 billions of cubic feet of gas.

The latter two items are equivalent on a Btu basis to approximately 86,000,000 tons of coal, accounting for roughly one-third of the kilowatthour output.

Just what do the above figures mean in terms of the total amount of these fuels used? The U. S. Bureau of Mines reports that the electric utilities account for about 43% of the total domestic use of coal. The next largest classified uses are listed as the coke and gas plants—83,000,000 tons, and retail dealers—34,000,000 tons.

In the fuel oil field, the American Petroleum Institute indicates that the gas and electric industry accounts for about 15% of the residuals ordinarily used for steam-power boilers.

In the natural gas field, the figures of the American Gas Association indicate that about 15% of the marketed production is used for the electric light and power industry. This latter, for the most part is used under the boilers in the natural gas producing states.

Natural gas as a boiler fuel presents almost no air pollution problem. In certain locations and under certain conditions its use as a boiler fuel is highly desirable. In most localities, oil as a boiler fuel, used in properly designed boilers and with adequate stacks, causes little difficulty, insofar as particulate matter, and even noxious gases, are concerned.

I am well aware of the special conditions existing in Los Angeles, and some other localities, where meteorological conditions are unusual. For most locations, however, including the New York area—again with the proviso that proper height, temperature, and exit velocities are maintained—SO_2 and other objectionable constituents of the flue gas from power plant stacks can rarely be measured at habitable levels.

Coming to coal which, up to the present and apparently for the foreseeable future, will be the power industry's main source of energy, there has always been the problem of taking care of particulate matter discharged from the stacks. For a great many years, in the not too distant past, the problem was always referred to as a smoke problem. Our own association and other similar groups were generally known as Smoke Abatement or Smoke Control Associations.

Smoke is technically the unburned carbon in fuel. Most large users of coal (and certainly the electric power industry) have learned how to burn the fuel very completely. With an almost complete swing to pulverized coal as against various types of stokers, modern boiler design has enabled the industry to attain a very creditable record in efficiency of combustion. For this progress the industry does not claim that it deserves any very special credit. The efficient burning of fuel is obviously to the advantage of the companies and, through the lowering of the cost of production, to the advantage of their customers.

For the past few years, the main problem in the burning of coal has been the control of fly ash. Although the coals ordinarily used vary considerably in the amount of ash they contain, a fair average in this country seems to be about 8%. Depending upon the type of boiler, anywhere from about half to nearly 90% of this ash would be discharged into the atmosphere if no control methods were used. It takes but a simple calculation to indicate the terrific quantities that would be released without control equipment.

For the most part, the fly ash under efficient burning contains relatively small amounts of entrained carbon. It certainly is not particularly dirty when compared with the sooty deposits from inefficient or improperly adjusted liquid fuel burners. However, it is, of course, an obvious nuisance and cannot be tolerated in any great quantity in these more enlightened days.

Although the electric utility companies for many years used various mechanical devices to catch cinders and fly ash particles, it was the electrostatic precipitator that came mainly to the aid of the industry. These have been installed with increasing effectiveness until the efficiency in fly ash removal now reaches the upper 90%'s. Combined with the latest improved design of mechanical collectors, efficiencies of better than 99% are being attained. It has been with the control of fly ash that the greatest progress has been made, and the largest expenditures encountered.

I have gathered information on the total expenditures made by the electric light and power industry for air pollution control. The figures do not include the cost of changes made purely for obtaining increased efficiencies in combustion, nor do they include the increased maintenance and operating costs occasioned by the installation of control equipment.

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

The total amount expended or appropriated, for work now under way, can be conservatively stated to have passed the $350,000,000 mark. This covers the period since World War II and includes both the investor-owned utility companies and the government-owned systems, of which the TVA is, by far, the largest. There is, naturally, considerable variation in the expenditures in different parts of the country. For example, in the southwest, where natural gas is used to such a great extent, there is relatively little capital expense for air pollution control. Expenses run very high for those companies whose plants are located in the midst of heavily populated areas, as compared with those whose plants are remote. On the other hand, heavy expenditures have also been made on plants in river valleys, where population density is relatively light, but there is possibility of severe damage to vegetation.

The costs can run high. A combined mechanical and electrostatic installation for a 360,000 kw unit today costs about $5,000,000. This represents an investment in air pollution control equipment of about $14 for each kilowatt of customer demand.

In addition to the expenditures made for equipment, much money has been spent by utility companies in the search for even better control methods. The funds have gone to research organizations, to schools and other groups that might come up with worth-while answers. These activities are well known to the Association and have been the subject of many papers presented at its meetings.

Costs, while impressive, do not alone give a true picture of the utility companies' efforts in this direction. For more than ten years a very appreciable part of my time has been connected in one way or another with air pollution matters.

I have found, somewhat to my surprise, that I have visited most of the larger cities in this country and Canada. Just the other day I checked the advance estimates of the populations of U. S. cities for 1960. These indicate that there are 324 cities with a population of 50,000 or more. I have visited all but 16 of them. It begins to look as though one of my hobbies was the collection of cities. This, to a great extent, is true, since on numerous trips I have tried to cover as wide a field as possible. It so happens that much of this travel has coincided with my active interest in air pollution. I doubt if many have been in so many different locations.

I am, admittedly, a public utility man and I have been particularly interested in utility companies, their distribution systems, their plants, and—for the purpose at hand—their methods of air pollution control. Against this background I must express my very firm conviction that this industry has made a most remarkable record in the fight for cleaner air.

In making heavy expenditures, the industry cannot fall back on savings to be accomplished. Fly ash has been established as useful in the manufacture of concrete, but any return from this source is infinitesimal compared with the expenditures made. Also, any devices placed in the air stream must, to a greater or lesser extent, increase the costs of production. Maintenance of the equipment to clean such great masses of flue gas, and handle such large quantities of fly ash, represents a substantial part of the maintenance and operating costs of the electric utility companies.

In seaboard areas, a large part of the ash must be carted to sea for dumping. At inland plants, large areas must be provided for the disposal of the ash in land-fill operations. In spite of these difficulties, I have found an almost universal feeling on the part of engineers, operating men, and executives that they must do their best to control air pollution from their plants as a duty to the community.

It is evident, from looking into the history of these operations, that expenditures were undertaken long before any great pressures were exerted upon the utility companies. Frequently, this was done many years before the adoption of air pollution control ordinances and the formation of air pollution control departments. I must add that I am not so naive as to think that the pressures of public opinion (through organizations and the press as well as those exerted by the enforcement agencies) do not act as a very real catalyst in increasing the activities of utility companies, and speeding up their program.

One of the most disheartening facts in this work of air pollution control is the seeming lack of appreciation on the part of the public of the efforts we are making and the progress attained. We try to tell our story through the press, sometimes through advertising and other media, but all too often we fail to get our message across. I am quite convinced that there is only one sure-fire, effective way of getting the story across and that is through personal visits to plants by civic groups, political leaders, educators, and even those individuals who take only a personal interest in conditions. During the past few years there have been hundreds of these groups and individuals who have visited us at Con Edison. We are very careful to be extremely accurate in telling them what we have done, what we plan to do, and also to include items indicating our shortcomings. Almost universally, this method makes friends, even though we may not always present satisfactory proof that we have done as well as they expect we should.

During the last year or so, much interest in my company, Con Edison, has revolved around the fact that we are constructing an atomic energy plant at Indian Point on the Hudson River near Peekskill. The interest was so high that we built a special visitors' overlook building with models, and a place for showing a motion picture, as well as a good view of the construction under way. Since this overlook building was opened around the first of September 1959, we have had more than 70,000 visitors.

An interesting sidelight has come out of the questions asked. In telling the people about the plant, and emphasizing all the important safety provisions connected with its operation, we point out that the atomic fuel is not burned in the ordinary sense—and the products of atomic combustion are *not* discharged into the atmosphere. The fuel is enclosed in metal containers called fuel elements. The unburned fuel, as well as the waste products produced during the operation of the reactor, remains in the element until they are reprocessed to recover the unused fuel. As the result of this explanation, we are frequently asked if the increased use of plants employing atomic fuel rather than the ordinary fossil fuels would not greatly reduce air pollution. Of course this is true, but we have to point out that the present cost of atomic energy plants is considerably higher than for conventional plants, and that it will be some time before a substantial part of the country's requirements will be generated in nuclear fuel plants.

There is an interesting item connected with atomic energy in a release by the Department of the Interior Information Service on April 11, 1960. This has to do with the use of "depleted uranium," the material remaining after the removal of most of the fissionable component, U-235, in producing enriched atomic fuel. This material has been suggested as a smog inhibitor, when installed in automobile exhaust systems to convert the gases into harmless substances.

Getting our story across to the man in the street is much more difficult than getting it across to professional men and those having an intimate knowledge of the problems involved. I do not think, however, that we should feel too discouraged. It is only natural that people will point their fingers at us because of our very prominent stacks, as they also point their fingers at all stacks of other industries throughout the country. There will always be loud and vociferous objections as long as there

(*Continued on p. 303*)

SAMPLING STATION *and* TIME REQUIREMENTS *for Urban Air Pollution* SURVEY*

Part I: lead peroxide candles and dustfall collectors

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The Public Health Service Air Pollution Engineering and Air Pollution Medical Programs have conducted a joint study of air pollution in Nashville, Tennessee.

A general description of the study will be presented during the course of this meeting.[1] Objectives of the study, in general, were to investigate possible relationships between air pollution and the health of the people, and to obtain information on a number of engineering and meteorological aspects of air pollution. Over 200,000 aerometric observations were obtained. One of the engineering objectives of the study was to determine representativeness of air quality data with respect to number and location of sampling stations, sampling frequency, and sampling time, as related to various uses of the data.

The major portion of the observations was applicable to the accomplishment of this objective, and the evaluation of this part of the data was directed toward answering these particular questions on sampling: (*1*) how frequently? (*2*) how long? (*3*) how many? and (*4*) where? The answers to these questions are rarely self evident or available from standard guide books on sampling. Logical theoretical approaches to the "how frequently" and "how long" questions have been suggested by some investigators.[2, 3, 4, 5] To some extent these investigators have approached, and others[6] have treated, the questions of "how many" and "where." Examination of air pollution field sampling reports to date reveals little or very limited actual sampling evidence to firmly support answers to the above questions.

This paper reports the results of the first phase of efforts to answer these questions. The results were obtained through the evaluation of over 2800 samples secured by the use of lead peroxide candles and dustfall collectors. Part II of this particular phase of the study is in progress and will pertain to a similar evaluation of sulfur dioxide and particulate samples collected for durations of 24 hours, two hours, and 30 minutes.

Methods

Collection and Analysis of Samples

Aerometric stations were established at 119 sites in the urbanized part of the Nashville area, and in addition, four control stations were situated approximately 7.5 miles from the center of the network. Each of the 119 stations was located as near as was feasible to the intersection of lines forming an equilateral-triangle-grid pattern. Stations were about 0.87 mile apart and the entire network covered a near-circular area about nine miles in diameter centered on downtown Nashville (Fig. 1-A).

At 32 of the 119 stations, more extensive measurements of pollution were made than at the other stations, and at seven of these 32, even more extensive sampling was conducted. The intended ideal spacing of the 32 stations was to be twice that of the entire network

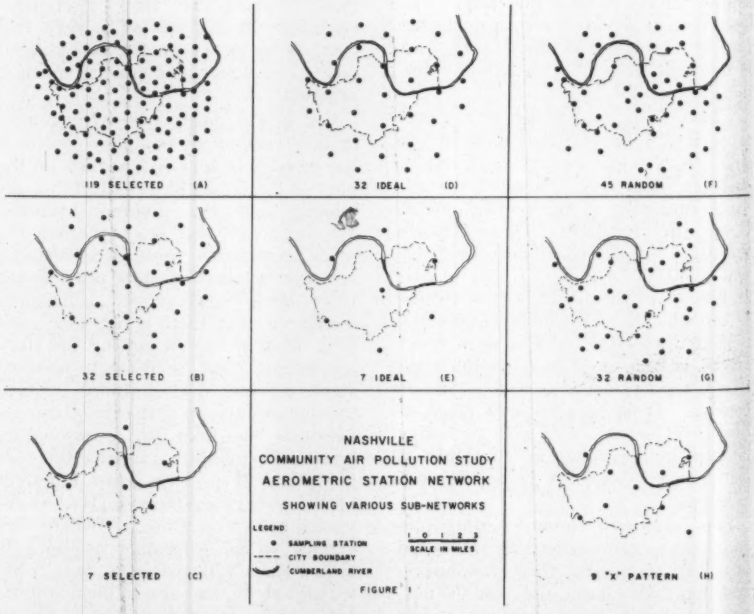


Fig. 1.

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 23, 1960, Cincinnati, Ohio.

(1.74 miles apart) and for the seven stations was to be four times (3.48 miles apart). However, for various reasons (e.g., meteorological instrument advantages and availability of electrical power), the actual locations selected were somewhat at variance from the ideal and for the purposes of this paper have been identified as the "32 selected" (32 S) and "seven selected" (7 S) networks (Fig. 1-B and C).

For purposes of statistically evaluating possible advantages of using the intended ideal (uniformly spaced) or of using randomly-spaced stations, and for simultaneously determining the least number of stations required, smaller networks of "ideal" and "random" station groupings were chosen from the large network. These subnetworks are identified as "32 ideal" (32 I), "seven ideal" (7 I), "45 random" (45 R), and "32 random" (32 R) (Fig. 1-D, E, F, and G).

In addition to these groupings, which represent only a fraction of the possible combinations of stations, several other groupings which seemed logical for air pollution monitoring purposes were chosen. Of these, only the "9 X" pattern gave results which were at all comparable to those obtained with the entire network (Fig. 1-H). This network is comprised of every other station lying on the principal diagonals of the triangular grid of 119 stations.

One lead peroxide candle sampler and one dustfall collector were located at each of the 119 urban and four control sampling stations. Over 1400 monthly samples of each type were collected during the one year of study.

Basically the lead peroxide candle sampler (which is housed in a protective shelter 11 feet above the ground) consists of a cylinder around which is wrapped a gauze coated with a paste containing lead peroxide. The sampler affords a measure of the sulfation rate of the ambient atmosphere. The amount of sulfation (mgms SO_3/100 sq cm/day) was determined by a Tennessee Valley Authority modification of the standard gravimetric sulfate method[1] which was developed in 1932 by Wilsdon and McConnell.[7] A close relationship between lead peroxide sulfation rates and sulfur dioxide levels has been reported by others.[8] In Nashville it was noted that there was a striking similarity between the geographic distribution of mean sulfation rates as measured by lead peroxide candles, and the mean sulfur dioxide levels as measured by the more specific West and Gaeke method[9] (Fig. 2).

The dustfall collector was located immediately above the lead peroxide candle at each sampling station. The collector was simply a plastic waste paper basket and when first set out each time contained two liters of water with an algicide in solution. The methods of collection and analysis[1] were essentially those recommended by the Air Pollution Control Association.[10] The amount of dustfall (tons/sq mi/mo) was determined by weighing the water insoluble matter. (Detailed analysis of ten percent of all monthly samples indicated that the water insoluble fraction was approximately 57% of the total dustfall in this community.)

Statistical Evaluation of Sample Data

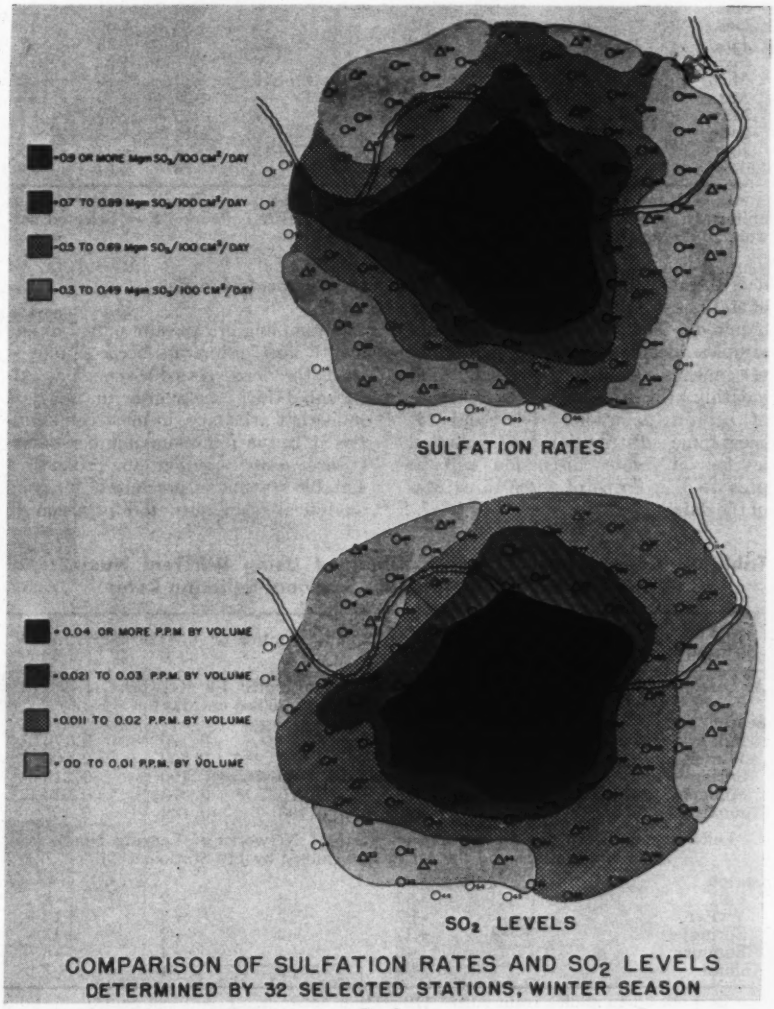
It has been shown that distributions of measurements of particulate pollutants tend to be approximately log normal.[2] Not only was this characteristic confirmed, but also the analysis of distributions of concentrations of gaseous pollutants indicated a similar characteristic. Therefore, consistent with the assumption of log normality, the measure of central tendency used in this paper is the geometric mean. Likewise, the measure of variability (i.e., the spread of values about their mean) is the geometric standard deviation.

Other statistical techniques used are: (*1*) student "t" test for the determination of the significance of differences between means; in all cases the 95% confidence level was used, (*2*) "F" test to determine the significance of difference in variance, (*3*) coefficient of variation to indicate relative percent deviation of individual measurements from the mean.

In view of the quantity of data considered and the statistical techniques used, it was necessary to make use of an electronic computer. Several computer programs were designed and written specifically for this study.

Results and Discussion

As indicated in the statement of the primary study objective presented in the first paragraph of this paper, it is necessary to first define the use that is to be made of the sampling data before


0.9 OR MORE Mgm SO3/100 CM²/DAY
0.7 TO 0.89 Mgm SO3/100 CM²/DAY
0.5 TO 0.69 Mgm SO3/100 CM²/DAY
0.3 TO 0.49 Mgm SO3/100 CM²/DAY
SULFATION RATES
0.04 OR MORE P.P.M. BY VOLUME
0.021 TO 0.03 P.P.M. BY VOLUME
0.011 TO 0.02 P.P.M. BY VOLUME
0.00 TO 0.01 P.P.M. BY VOLUME
SO2 LEVELS

COMPARISON OF SULFATION RATES AND SO_2 LEVELS DETERMINED BY 32 SELECTED STATIONS, WINTER SEASON

Fig. 2.

Table I—Comparison of Results Obtained Using Different Numbers of Sampling Stations to Measure Monthly Sulfation Rates

1958–59	Number of Groupings[a] of Stations in Network: 119 S	45 R	32 S	32 I	32 R	9 X	7 S	7 I
A. Monthly and Annual Mean Sulfation Rates Determined by Networks of Varying Numbers of Sampling Stations (mgm/100 sq cm/day)								
Month								
Aug.	0.075	0.080	0.068	0.069	0.075	0.077	0.106	0.065
Sept.	0.076	0.080	0.081	0.073	0.073	0.087	0.132	0.073
Oct.	0.192	0.199	0.220	0.198	0.216	0.238	0.434	0.227
Nov.	0.341	0.358	0.340	0.318	0.369	0.442	0.721	0.305
Dec.	0.594	0.627	0.611	0.587	0.684	0.833	1.003	0.670
Jan.	0.552	0.582	0.588	0.572	0.628	0.604	1.011	0.591
Feb.	0.468	0.482	0.516	0.491	0.497	0.640	0.809	0.550
Mar.	0.348	0.345	0.420	0.415	0.403	0.520	0.623	0.426
Apr.	0.225	0.232	0.230	0.217	0.234	0.284	0.390	0.267
May	0.079	0.074	0.091	0.077	0.068	0.091	0.102	0.080
June	0.069	0.074	0.071	0.072	0.055	0.080	0.095	0.068
July	0.076	0.076	0.068	0.067	0.085	0.072	0.084	0.069
Annual	0.190	0.195	0.198	0.188	0.196	0.226	0.312	0.195
Confidence limits	0.180 to 0.200	0.178 to 0.214	0.178 to 0.220	0.170 to 0.209	0.175 to 0.219	0.182 to 0.279	0.247 to 0.394	0.153 to 0.247
B. Difference Between the Mean Sulfation Rates for Networks of Varying Numbers of Sampling Stations and the Mean Determined by Network of 119 Stations (%)								
Month								
Aug.	—	+6	−9	−8	0	+3	+41	−13
Sept.	—	+5	+7	−4	−4	+14	+74	−4
Oct.	—	+4	+15	+3	+13	+24	+126	+18
Nov.	—	+5	0	−7	+8	+30	+111	−11
Dec.	—	+6	+3	+1	+15	+40	+69	+13
Jan.	—	+5	+7	+4	+14	+9	+83	+7
Feb.	—	+3	+10	+5	+6	+37	+73	+18
Mar.	—	−1	+21	+19	+16	+49	+79	+22
Apr.	—	+3	+2	−4	+4	+26	+73	+19
May	—	−6	+15	−3	−14	+15	+29	+1
June	—	+7	+3	+4	−20	+16	+38	−1
July	—	—	−11	−12	+12	−5	+11	−9
Annual	—	+3	+4	−1	+3	+19	+64	+3

[a] R = Random choice from entire 119-station network. I = Ideal choice—stations uniformly spaced. X = "X" pattern centered upon entire network. S = Selected network to meet various sampling requirements.

it is possible to determine the number of stations or the frequency of sampling required. The uses made of monthly samples include the determination of (*1*) means—annual, seasonal, and monthly, (*2*) frequency of occurrence of certain pollution levels, and (*3*) geographic distribution of pollution levels. Therefore, discussion will be presented in terms of these three uses of the data.

Lead Peroxide Candles

A sampling or exposure period of one month has ordinarily been employed with the lead peroxide candle.[7] Although this one-month duration is somewhat arbitrary, in most communities it is the minimum number of exposure days required to produce a suitable amount of precipitate for good analytical techniques and precision (5 to 2000 milligrams of barium sulfate). Monthly lead peroxide samplers were used in the study for two principal reasons relative to the characterization of sulfation rates in the community: (*1*) because of their field and laboratory economy, a great number of samples could be used, could be stationed at short distances apart, and thus could provide good geographic coverage of the area, and (*2*) the monthly samples were expected to provide not only a good measure of variation between months and seasons for the over-all community but also a reasonably good measure of seasonal and annual variation between sample locations. Due to the inherent error found in the individual measurements, monthly samples do not, for any one month, provide a reliable measurement of geographic variation in pollution over the community.

Number and Spacing of Sampling Stations

The design of the sampling network at Nashville was such that it was only natural to compare the entire urban network of 119 stations and the two "selected" sub-networks of 32 and seven stations each. Furthermore, the design afforded an opportunity to choose other networks for similar comparison. The excellent agreement between two of these sub-networks with the entire network is illustrated for the various months, the seasons, and for the year (Fig. 3).

The annual geometric mean sulfation rates for the community, as estimated by selected, smaller station networks, generally agreed quite well with that for the entire urban network (Table I). Of the very small networks the mean of the seven selected stations proved to be significantly different from the 119 stations, but the 9 X network (approaching uniform spacing) and the seven ideal network (uniform spacing) were not significantly different from the 119.

It must be remembered, however, that the reliability of these estimates is a function of the number of stations involved as well as the distribution of sample values. For example, note that the mean as computed from the seven ideal stations was essentially the same as that for the 119 stations, but the 95% confidence interval shows that this is a less reliable estimate of the true mean than that determined by the 119-station or 32-station (ideal) networks.

Seasonal sulfation rates for several smaller networks were similarly compared with those for the entire network (Table II). Any of the three 32-station networks provided a good estimate of the seasonal mean for the entire network, but the 32 ideally-spaced stations gave consistently closer estimates. Dif-

Table II—Comparison of Results Obtained Using Different Numbers of Sampling Stations to Measure Seasonal Sulfation Rates

1958–59	Number of Groupings[a] of Stations in Network: 119 S	32 S	32 R	32 I	7 I
A. Season and Annual Mean Sulfation Rates Determined by Networks of Varying Numbers of Sampling Stations (mgm/100 sq cm/day)					
Season					
Fall	0.173	0.185	0.180	0.170	0.170
Winter	0.536	0.571	0.600	0.550	0.600
Spring	0.186	0.208	0.190	0.190	0.210
Summer	0.073	0.069	0.070	0.070	0.070
Annual	0.190	0.198	0.196	0.188	0.195
B. Difference Between the Mean Sulfation Rate of Networks of Varying Numbers of Sampling Stations and the Mean Determined by 119 Stations (%)					
Season					
Fall		+7	+4	−2	−2
Winter		+7	+12	+3	+12
Spring		+12	+2	+2	+13
Summer		−6	−4	−4	−6
Annual		+4	+3	−1	+3

[a] R = Random choice from entire 119-station network. I = Ideal choice—stations uniformly spaced. S = Selected network to meet various sampling requirements.

MILLIGRAMS SO3 PER 100 SQUARE CENTIMETERS PER DAY
0
.2
.4
.6
.8
SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APRIL MAY JUNE JULY AUG. ANNUAL MEAN
MONTH
119 SELECTED
32 SELECTED
7 IDEAL
MEAN SULFATION
DETERMINED BY THREE SAMPLING NETWORKS
FALL
WINTER
SPRING
SUMMER
ANNUAL MEAN
SEASON

Fig. 3.

32 SELECTED SAMPLING STATIONS
119 SAMPLING STATIONS
ANNUAL MEAN SULFATION
DETERMINED BY NETWORKS OF 32 AND 119 STATIONS

Fig. 4.

Table III—Comparison of Variabilities of Monthly Sulfation Rates over the Urban Area as Measured by Different Numbers of Sampling Stations (Coefficient of Variation in Percent)

1958–59	Number and Groupings[a] of Stations in Network: 119 S	45 R	32 S	32 I	32 R	9 X	7 S	7 I
Month								
Sept.	97	123	97	110	91	129	80	132
Oct.	106	142	83	81	112	143	68	125
Nov.	92	103	108	107	130	116	48	170
Dec.	66	76	56	61	77	71	36	57
Jan.	94	78	65	66	84	153	47	82
Feb.	75	87	60	68	97	85	40	69
Mar.	101	105	86	92	86	95	48	81
Apr.	72	67	59	59	72	62	42	58
May	96	105	116	129	105	62	191	135
June	70	91	69	63	94	54	35	57
July	82	105	44	43	158	51	17	56
Aug.	62	72	60	55	47	84	94	97
Season								
Fall	151	—	145	150	176	—	—	185
Winter	80	—	60	65	89	—	—	66
Spring	144	—	144	162	169	—	—	163
Summer	71	—	58	54	105	—	—	67
Annual	181	192	181	184	213	205	195	204

[a] R = Random choice from entire 119-station network. I = Ideal choice—stations uniformly spaced. X = "X" pattern centered upon entire network. S = Selected network to meet various sampling requirements.

Table IV—Comparison of Results Obtained Using Different Numbers of Sampling Stations to Measure Monthly Dustfall Levels

1958–59	Number of Groupings[a] of Stations in Network: 119 S	45 R	32 S	32 I	32 R	9 X	7 S	7 I
A. Monthly and Annual Mean Dustfall Levels Determined by Networks of Varying Numbers of Sampling Stations (tons/sq mi/mo)								
Month								
Aug.	6.4	5.5	5.8	5.7	5.8	5.9	5.7	5.5
Sept.	6.7	6.8	4.7	5.4	5.7	5.7	8.3	3.6
Oct.	7.9	8.0	6.0	5.6	8.1	7.5	10.3	6.7
Nov.	5.6	5.5	3.6	3.3	5.8	5.3	5.5	4.4
Dec.	5.5	4.8	4.0	3.9	4.9	6.0	6.6	5.2
Jan.	5.0	4.5	3.1	3.2	4.0	4.9	6.9	2.3
Feb.	7.1	7.5	5.1	5.8	6.1	6.4	6.0	4.6
Mar.	7.3	7.9	6.1	6.1	7.4	7.1	11.1	5.9
Apr.	9.3	9.5	8.7	7.9	9.5	11.0	13.0	7.7
May	5.0	5.8	5.3	5.1	5.6	6.3	9.3	5.3
June	5.3	5.3	4.8	5.0	6.1	7.4	7.4	6.6
July	7.8	8.0	6.7	5.8	8.2	5.6	14.0	7.0
Annual	6.5	6.4	5.2	5.0	6.1	6.3	8.3	5.2
Confidence limits	6.2 to 6.8	5.9 to 7.0	4.8 to 5.7	4.5 to 5.5	5.6 to 6.7	5.4 to 7.4	7.0 to 9.8	4.2 to 6.3
B. Difference Between the Mean Dustfall Levels for Networks of Varying Numbers of Sampling Stations and the Mean Determined by Network of 119 Stations (%)								
Month								
Aug.	—	−15	−10	−11	−10	−9	−12	−15
Sept.	—	+1	−21	−30	−19	−15	+24	−46
Oct.	—	0	−24	−30	+2	−6	+29	−16
Nov.	—	−2	−35	−42	+4	−4	−1	−21
Dec.	—	−13	−28	−30	−12	+8	+19	−6
Jan.	—	−9	−36	−36	−19	−2	+38	−54
Feb.	—	+6	−28	−18	−15	−9	−15	−35
Mar.	—	+8	−16	−16	+1	−3	+53	−19
Apr.	—	+2	−6	−15	+1	+19	+40	−17
May	—	+16	+7	+2	+12	+25	+85	+5
June	—	+1	−10	−10	−5	+16	+41	+25
July	—	+2	−14	−26	+4	−28	+78	−11
Annual	—	−1	−20	−23	−5	−2	+28	−20

[a] R = Random choice from entire 119-station network. I = Ideal choice—stations uniformly spaced. X = "X" pattern centered upon entire network. S = Selected network to meet various sampling requirements.

ferences between seasonal means for the seven ideally-spaced network and the entire network were not statistically significant and, in fact, were no larger than the variation noted in two of the 32 station networks.

In the determination of monthly means, it is logical that the number and spacing of stations in the network is a more critical factor than in the case of seasonal and annual means. Comparing these means for various networks, the monthly mean sulfation rate of the 45 randomly-chosen stations differed from those of the entire network by no more than seven percent (Table I-B) and none of the differences was statistically significant. In the comparison of the various 32-station groupings, the "ideal" network appears to be the slightly better choice because the monthly means for this grouping generally differ from the means of the entire network by a smaller amount, and again none was significantly different. Further inspection of Table I-B indicates that it would ordinarily be unwise to attempt to estimate the monthly mean sulfation rate by the 9 X or 7 S networks. The surprisingly good agreement between the monthly means of the seven ideal stations and those of the entire network allows the authors to postulate that, as the number of stations is reduced, uniform spacing of samplers becomes a more important consideration.

Close agreement between mean values obtained from the large and small networks of stations is not the only criterion for establishing the size of a network. Additional information needed to characterize air pollution more adequately is the "cumulative frequency distribution," or "frequency of occurrence of certain pollution levels." The two "ideal" networks showed the closest agreement with the cumulative frequency distribution of the entire network whether determined for the entire 12 months or for seasons when plotted on logarithmic probability paper.

Still another purpose for which monthly sample data are used is that of describing annual and seasonal geographic distributions of pollution. Isopleth maps of the annual mean sulfation rates by sampling site show excellent similarity between patterns described by 32 and 119 "selected" stations (Fig. 4). Although the geographic distribution of sulfation is approximately represented by the smaller network of 32 stations, some of the finer geographic details depicted by the 119-station network are lost. The loss of these finer geographic details ordinarily is of little, if any, importance to the over-all community air pollution picture. However, in an epidemiological or health-effects air pollution investigation geographic variations in pollution are of

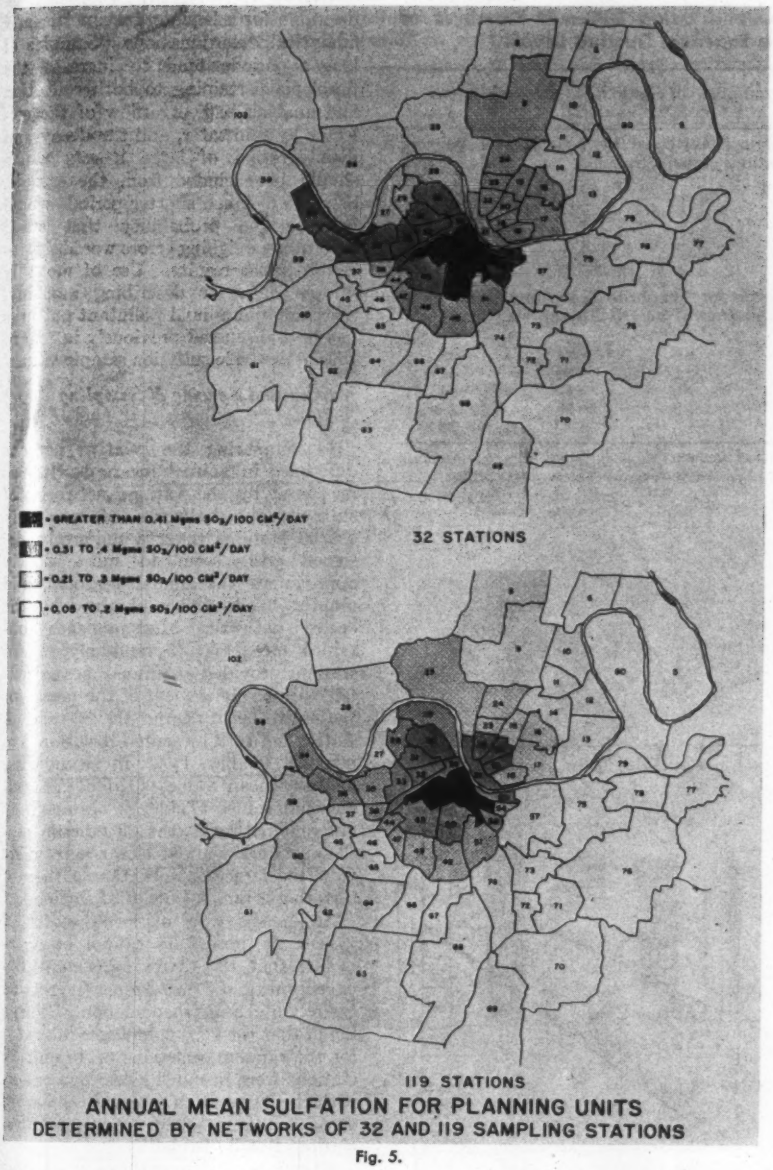

GREATER THAN 0.41 Mgms SO3/100 CM2/DAY
0.31 TO .4 Mgms SO3/100 CM2/DAY
0.21 TO .3 Mgms SO3/100 CM2/DAY
0.05 TO .2 Mgms SO3/100 CM2/DAY
32 STATIONS
119 STATIONS
ANNUAL MEAN SULFATION FOR PLANNING UNITS
DETERMINED BY NETWORKS OF 32 AND 119 SAMPLING STATIONS

Fig. 5.

prime importance. For example, in the Nashville investigation, families living in a five percent random sample of households were interviewed and it was desired to relate the epidemiological data collected to air pollution levels for small geographic areas called "planning units" (neighborhoods). Thus it was particularly desirable that the pollution levels for each planning unit be rather accurately described. When maps were prepared showing annual mean sulfation rates by planning units, it was noted that about 20% of the units on the 32-station map had been assigned values different from those of the more accurate map based on the 119-station network (Fig. 5). Should this difference in sulfation rates be shown to be significant in causing health effects, it could then be concluded that, for the purpose of supporting this health-effects study, it would be necessary to use the pollution levels described by the entire network rather than the smaller one.

Frequency of Sampling

The frequency of sampling preferred by any investigator is certainly the one which will adequately characterize air pollution for the area of interest with a minimum expenditure of time and money. The qualification of "adequately characterize" is based upon the intended use of the data (i.e., annual, seasonal, and monthly means; frequency distributions or geographic patterns) and the accuracy desired which must be specified by the investigator for each set of circumstances.

The annual means determined by samples collected every other month (either on even-numbered or odd-numbered months) were not significantly different from the mean determined by sampling all 12 months, in fact they differed by only about five percent. Likewise, annual means determined from samples collected during the four mid-seasonal months (i.e., October, January, April, and July) were also not significantly different from the 12 months mean (10% difference).

This latter sampling schedule would have had the additional advantage of providing a fairly close estimate of the respective seasonal mean sulfation rates. When mid-month means were compared to the means for the respective seasons (Tables I and II) it was noted that the April mean was significantly different (21%) from the mean for spring (the most variable season), but all other mid-month values were within 12% of the seasonal rates and these differences were not statistically significant.

It is interesting to note the similarity between spring, fall, and annual distributions of sulfation rates, and the dissimilarity between winter, summer, and annual distributions (Table III and Fig. 6). The smaller variation for winter and summer might well be explained by the fact that the sulfur dioxide sources are consistently high in the winter and low in the summer because they are a function of temperature and resulting use or nonuse of space heating. In contrast, the greater slope of the spring and fall plots indicates greater variability in meteorological factors with resultant greater variability of sulfation values during these seasons. The fact that the slopes of the spring and fall plots closely parallel the annual plot suggests that where limitations of time or money dictate the necessity of a short survey, the investigator should choose either the spring or fall months and thus not only measure the pollution during the season, but also obtain a reliable estimate of the annual mean and frequency distribution. Since unusually high levels of pollution are most likely to occur during the fall this season would be the choice of the two.

Geographic distribution patterns of annual mean sulfation based upon determinations made by the 119- and 32-station networks have been shown (Fig. 4). From the findings reported thus far, there is good reason to believe that comparable maps based on sampling every other month with the same network, or for that matter, during the spring or fall season only, would show similar patterns.

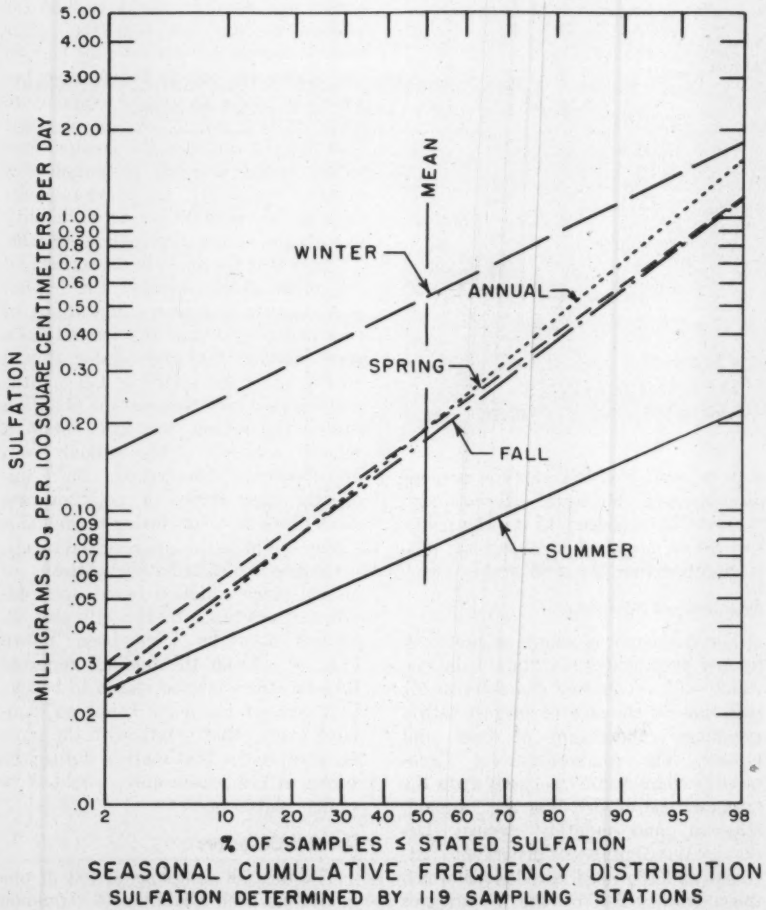
Dustfall Collectors

The dustfall sampling period of one month has been established by common practice.[10] This period of time is also

Table V—Comparison of Results Obtained Using Different Numbers of Sampling Stations to Measure Seasonal Dustfall Levels

1958–59	Number and Groupings[a] of Stations in Network 119 S	32 S	32 R	32 I	7 I
A. Seasonal and Annual Mean Dustfall Levels Determined by Networks of Varying Numbers of Sampling Stations (tons/sq mi/mo)					
Season					
Fall	6.7	4.8	6.4	4.4	4.8
Winter	5.8	4.0	5.1	4.2	3.8
Spring	7.0	6.6	7.4	6.3	6.2
Summer	6.4	5.7	6.2	5.4	6.3
Annual	6.5	5.2	6.2	5.0	5.2
B. Difference Between the Mean Dustfall Levels for Networks of Varying Numbers of Sampling Stations and the Mean Determined by 119 Stations (%)					
Season					
Fall	—	−28	−4	−34	−28
Winter	—	−31	−12	−28	−34
Spring	—	−6	+6	−10	−11
Summer	—	−11	−3	−16	−2
Annual	—	−20	−5	−23	−20

[a] R = Random choice from entire 119-station network. I = Ideal choice—stations uniformly spaced. S = Selected network to meet various sampling requirements.



SEASONAL CUMULATIVE FREQUENCY DISTRIBUTION
SULFATION DETERMINED BY 119 SAMPLING STATIONS

Fig. 6.

desirable for adequate gravimetric and analytical determinations. Samples of longer periods tend to increase the problems pertaining to both collection and analysis, e.g., overflow of the collector by rainwater, and the decay and disintegration of large insects which should be excluded from the sample. Samples of much shorter periods would increase the probability that small laboratory weighing errors would significantly affect results. Use of monthly sample data for describing monthly, seasonal, and annual pollutant patterns has been discussed previously in regard to lead peroxide sulfation sample values.

Number and Spacing of Sampling Stations

In comparing the relative percent difference in annual mean dustfall as measured by the various networks of stations, the networks of randomly spaced stations (over a uniformly designed grid) seem to most closely approximate the annual, seasonal, and monthly mean values obtained by the entire network. Measurements obtained using the 45 randomly placed stations provided an annual mean dustfall within one percent of the mean for the entire network and the 32-random station network measured it within five percent (Table IV). In comparing monthly-mean values (Table IV) and seasonal values (Table V) obtained by different networks, the 32 random station network showed closer agreement with the large network than either of the other arrangements of 32 stations.

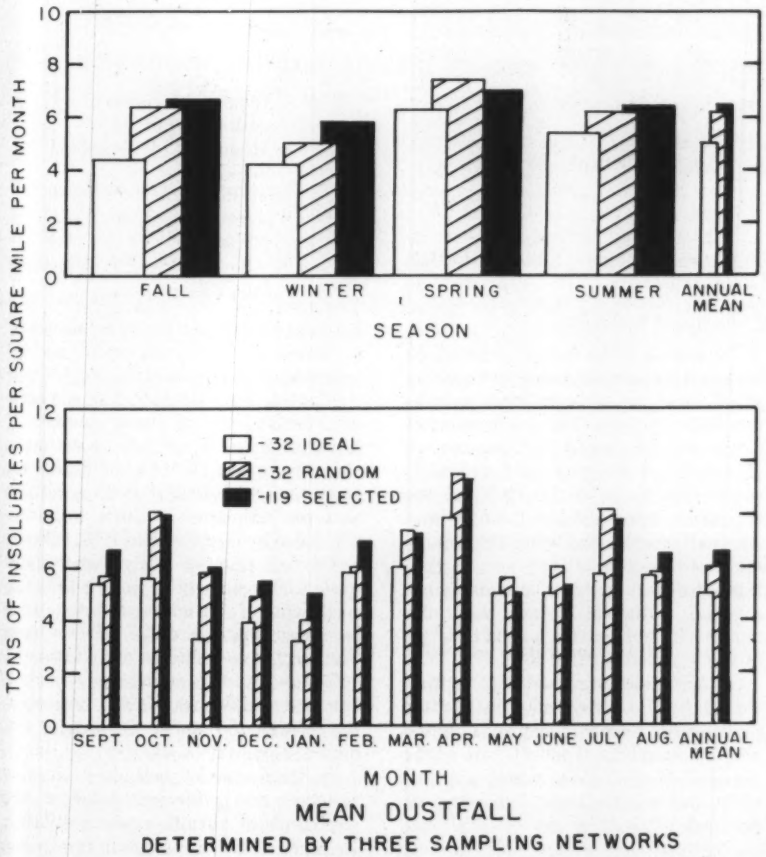
As in the case of mean sulfation values, the possibility cannot be overlooked that the above agreement between mean dustfall values might be entirely a chance phenomenon. It was found that the 95% confidence intervals for the random selections of 45 and 32 stations were in much closer agreement with the 119-station interval than were those for any other arrangement of stations tested (Table IV).

Therefore, the hypothesis presented earlier regarding the importance of uniform spacing of sampler stations for sulfation rate determinations does not appear to apply to dustfall. Rather, it is apparent from these studies that the randomized type of dustfall station spacing is superior when networks of at least one station for each two square miles (32 stations or more in the Nashville study) are employed to estimate annual and seasonal mean dustfall (Fig. 7). A precautionary note should be added, however, concerning the use of small numbers of stations for estimating annual means of a deposited pollutant such as dustfall as contrasted with a diffused gaseous pollutant such as sulfur dioxide. There is undoubtedly a critical number of stations below which the desired approximation of dustfall

Table VI—Comparison of Variabilities of Monthly Dustfall Levels over the Urban Area as Measured by Different Numbers of Sampling Stations (Coefficient of Variation in Percent)

1958–59	Number and Groupings[a] of Stations in Network							
	119 S	45 R	32 S	32 I	32 R	9 X	7 S	7 I
Month								
Sept.	133	128	148	128	126	81	235	138
Oct.	148	141	105	127	102	120	98	104
Nov.	207	225	183	197	188	190	189	335
Dec.	171	226	132	177	206	81	106	105
Jan.	227	217	259	251	294	305	131	364
Feb.	104	90	108	124	130	83	99	98
Mar.	122	112	135	139	146	140	47	137
Apr.	111	130	104	128	125	67	56	107
May	118	141	114	130	105	94	44	140
June	86	84	65	70	90	62	58	65
July	118	130	139	153	112	212	68	94
Aug.	169	159	144	176	179	169	196	146
Season								
Fall	165	—	149	155	144	—	—	185
Winter	170	—	169	189	211	—	—	191
Spring	125	—	122	135	133	—	—	122
Summer	128	—	119	133	134	—	—	97
Annual	147	154	144	156	155	130	116	151

[a] R = Random choice from entire 119-station network. I = Ideal choice—stations uniformly spaced. X = "X" pattern centered upon entire network. S = Selected network to meet various sampling requirements.



MEAN DUSTFALL
DETERMINED BY THREE SAMPLING NETWORKS

Fig. 7.

would not be reliable using a random selection of stations. The extreme case would be that of employing one station to estimate the mean for a particular area and it goes without saying that considerable judgment must be used in locating this station.

Regarding the frequency of occurrence of individual monthly dustfall levels over the area during the 12-month periods the results provided by the 45 and 32 random selections of stations approximate the frequency distribution determined by the entire network more closely than any other network used in the analysis of Nashville data. A similarly close agreement between the large network and the 32-random network was also demonstrated when these distributions were plotted for any one of the four seasons.

An isopleth map showing the geographic distribution of annual dustfall concentrations as measured by the network of 119 stations shows that the dustfall pattern over the community is erratic, and that consequently, the likelihood that erroneous patterns of geographic distributions will be presented is greater when smaller networks of stations are used (Fig. 8). This erratic distribution also serves to confirm the observation noted above that the random selection of stations (for networks above a certain critical size) provided the best estimates of the means.

In regard to monthly and seasonal dustfall levels and their variability presented in Tables IV, V, VI, and in Fig. 7, a short commentary seems in order at this point. The question of reliability of results will undoubtedly arise in the minds of many readers, because of: (*1*) the relatively low mean levels of monthly, seasonal, and annual dustfall measured in this community, and (*2*) the fact that the winter season shows the lowest mean seasonal dustfall. The mean dustfall levels shown here perhaps appear lower than levels indicated in many other dustfall studies because sample values, being log-normally distributed, were computed as geometric means in this study but as arithmetic means in many other studies. Also, the dustfall values used for all computations in this paper represent water insoluble dustfall only (which, in this community, is approximately 57% of total dustfall).

Perhaps, even another factor in this study appearing to reduce mean dustfall values was the extensive and intensive geographic sampling program (about two stations per urban square mile). About two-thirds of the stations were located outside of the city-limit-line proper but in the urbanized area. It may be noted (Table IV) that the small urban, 7 S, network showed an annual mean 28% higher

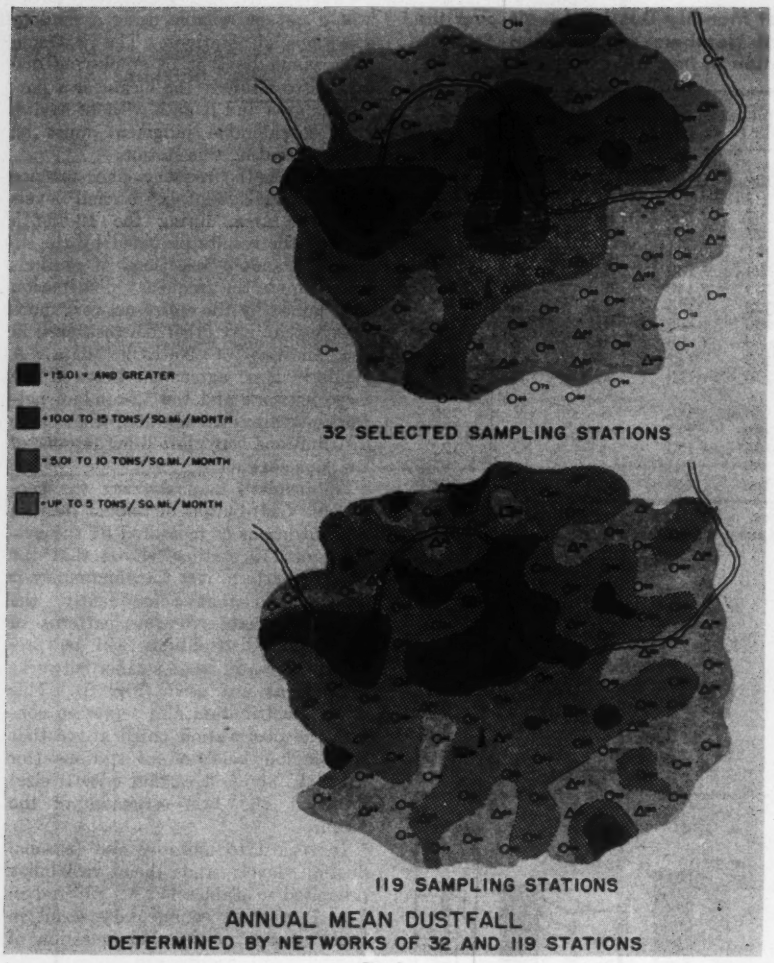

+15.01 + AND GREATER
+10.01 TO 15 TONS/SQ.MI./MONTH
+5.01 TO 10 TONS/SQ.MI./MONTH
+UP TO 5 TONS/SQ.MI./MONTH
32 SELECTED SAMPLING STATIONS
119 SAMPLING STATIONS
ANNUAL MEAN DUSTFALL
DETERMINED BY NETWORKS OF 32 AND 119 STATIONS

Fig. 8.

than the large network. It would be possible to select a specific network of seven urban stations which would show winter as the highest dustfall season. In this connection other investigators are urged to consider variability of dustfall over an area before concluding that a few samples from a small network will represent the true mean dustfall level over that area or community. In this study for example, the variability of dustfall during the winter season was such (170 C. V.) that the entire network (357 samples) would be required to give good assurance of estimating the true mean dustfall of the community within 18% (the theory of the true mean is discussed later in this paper).

One other environmental factor probably influencing the relative mean seasonal dustfall in the community studied was the unusually high tree and plant-life density over a large portion of the urban sampling network which resulted in significant visible deposits of plant debris in dustfall containers. This would, in part, explain low winter and high spring, summer, and fall dustfall levels.

Frequency of Sampling

The annual mean dustfall determined by sampling over the entire network on either even- or odd-numbered months was found to be within five percent of the mean determined by sampling all 12 months of the year, and with 95% confidence, to be within 10% of the true mean. Sampling on the four mid-seasonal months measured the annual mean within 13%. However, in contrast to the findings pertaining to seasonal sulfation rates, the mid-months did not provide a good estimate of the seasonal dustfall levels.

Another striking contrast is that shown by the frequency distribution plots for the seasonal means of sulfation and dustfall (Figs. 6 and 9). All of the seasonal dustfall plots closely approximate the annual slope indicating no seasonal variation in dustfall-producing processes comparable to that postulated for sulfur dioxide. Here again a sampling program limited in time would yield acceptable results if only one season, preferably the fall, were included.

Whether the geographic distribution of dustfall could be represented as well by lesser frequencies of sampling has not been investigated. However, the relatively high degree of variation throughout most of the year (Table VI) indicates that more sampling stations as well as more frequent sampling are required for estimating dustfall levels than for estimating sulfation rates.

Theoretical Determination of Number of Stations Required, and of True Mean

In the determination of the minimum number of sampling stations needed to estimate the true mean value for a given area, it is necessary to have some knowledge of both the relative variability of individual measurements for that area and the accuracy desired for the estimation. The former is expressed in terms of the coefficient of variation, defined as the ratio of standard deviation of the mean (in percent), and the latter as the allowable departure from the true mean. The minimum number of sampling stations can be computed from the following statistical relationship:[11]

$$N = \frac{(\text{C. V.})^2 t^2}{p^2}$$

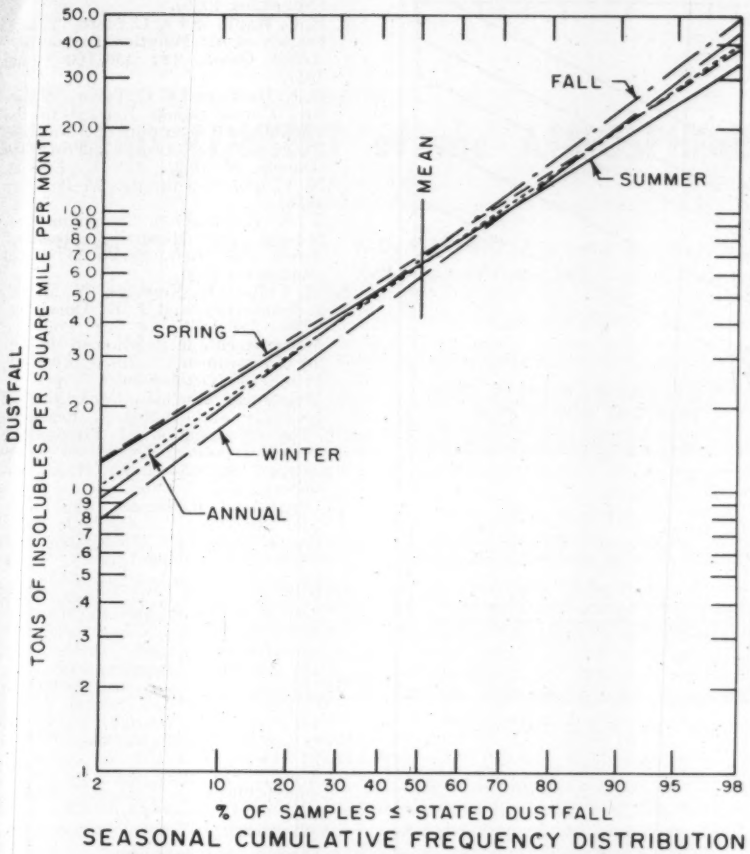
where

N = minimum number of stations required
t = student "t" for specified confidence
C. V. = coefficient of variation in percent = std. dev./mean $\times$ 100
p = allowable percent departure from the true mean

For convenience the above relationship is plotted on log-log paper for several values of p (Fig. 10).

Suppose, for example, it is required to determine the minimum number of stations needed to provide an estimate of the true mean level of a pollutant for a given area such that it is 95% certain that the estimate will differ from the true mean by no more than 10%. From a limited number of measurements made earlier, it may be known that the coefficient of variation for the area is approximately 40%. Then from Fig. 10, for a coefficient of variation of 40%, and a 10% difference between true and sample means (10% diagonal), the minimum number of stations required is found to be 60.

In the example just given, it was assumed that prior knowledge of the coefficient of variation was available. In practice the investigator rarely has definite knowledge of this variability.



SEASONAL CUMULATIVE FREQUENCY DISTRIBUTION
DUSTFALL DETERMINED BY 119 SAMPLING STATIONS

Fig. 9.

In such cases he can estimate the variability for the particular pollutant by operating a number of sampling stations over the area of interest for a limited period of time—say at least two months (for monthly samples). The best period of time for conducting this exploratory investigation would be that which the investigator feels represents the most variable time of the year. Evaluation of the Nashville data indicates that the optimum density of sampling stations was one station per two square miles and that autumn was a suitable period of time for the test (Tables III and VI, Figs. 6 and 9).

Another slightly different use of the graph is that of estimating how closely the mean of measurements obtained at a number of representative sampling sites approaches the true mean pollution level in the community after a study has been completed. When using the graph for this purpose, it is merely necessary to substitute "number of samples" for "number of stations" on the X-axis and thus obtain the reading in terms of sample numbers. In this study it was found that 1400 monthly sulfation samples, collected at 119 sampling stations, measured a mean annual sulfation rate of 0.190 mgm SO_3/100 sq cm/day over the urban area, and had a coefficient of variation of 181 percent (Table III). Referring again to Fig. 10 it is seen that for 1400 samples and a coefficient of variation of 181% the measured mean is most likely within 10% of the true mean sulfation for the area. Thus the graph precludes the necessity of the involved computation of confidence limits in the determination of the reliability of the mean as estimated by any size network.

It is to be noted that similar use of this graph shows that, for sulfation, the mean of any of the three networks of 32 stations satisfactorily approximates the true mean (within 23%).

Summary and Conclusions

Over 2800 monthly sulfation and dustfall samples were collected and analyzed during a one-year study of air pollution in Nashville, Tennessee. The resulting data were evaluated in terms of variation of pollutant levels with time and geographic location. This evaluation of data warranted the following conclusions pertaining to sulfation and dustfall samples of one month duration:

1. A selected network of seven uniformly-spaced lead peroxide air sampler stations estimated the mean seasonal and annual sulfation rates over the community about as well as the 119 stations actually used but with a considerably less degree of confidence.
2. Using two samplers per square mile (119 stations), the true annual mean sulfation rates and dustfall levels were estimated within 10% with a very high degree of confidence (95%). No less than this density of stations was required to adequately describe the geographic distribution for the purpose of supporting the health-effects phase of this study.
3. In the selection of sampling stations for the determination of sulfation rates or frequency distributions, uniformity of spacing appears to be the most important criterion; this becomes more apparent as the number of sampling stations is reduced.
4. In the selection of sampling stations for the determination of dustfall levels or frequency distributions, random selection of stations on a uniform network grid appears to be the most important criterion; again this became more apparent as the number of sampling stations was reduced.
5. Reducing the frequency of sampling to every other month results in annual means and frequency distributions of sample values within 10% of the corresponding values obtained by sampling all 12 months of the year and within 15% of the true mean.
6. When circumstances dictate the necessity for a sampling program of limited duration, it is possible, at least in communities resembling the area investigated in this study, to obtain reliable estimates of annual means and frequency distributions for both sulfation and dustfall by sampling only during the fall or spring season.

A statistical tool is provided and described which will assist any investigator in designing and evaluating his sampling program.

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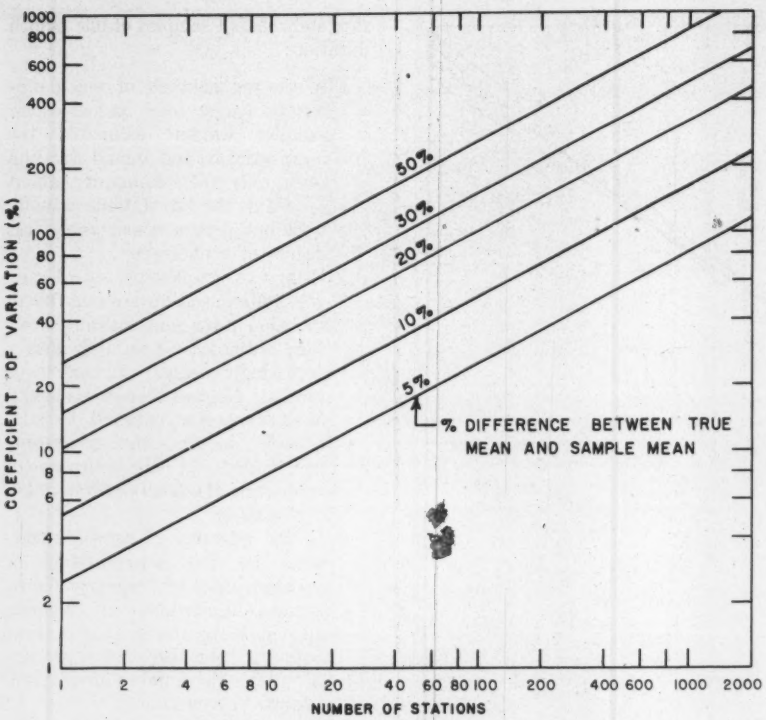

NUMBER OF STATIONS REQUIRED TO ESTIMATE TRUE MONTHLY MEAN WITHIN SPECIFIED LIMITS

Fig. 10.

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The LEAD CONTENT of the ATMOSPHERE*

J. CHOLAK, L. J. SCHAFER, and T. D. STERLING, The Kettering Laboratory in the Department of Preventive Medicine and Industrial Health, College of Medicine, University of Cincinnati, Cincinnati, Ohio

The general level of the concentration of lead in the air of large metropolitan centers has been the subject of more speculation and conjecture than of precise determination, for many years. Generally, the data presented for consideration have been too fragmentary to be representative of prevailing conditions with respect to variations from time to time or from place to place in the same community. Therefore, prolonged, virtually continuous investigations, involving a variety of sites, are needed to indicate trends which could be used as guides for the future establishment of hygienic standards.

Since 1946, members of the staff of The Kettering Laboratory have made many determinations of the levels of atmospheric lead at various sites in a number of cities, and have carried out an extensive and intensive program of air monitoring in Cincinnati, Ohio from January 1957 through December 1959. Analysis of the large volume of samples collected in the course of this program is still under way, but a sufficient number of analyses to show trends have been completed.

Procedures:

Collection of Samples

Samples of air-borne particulate lead have been collected in various ways, generally by electrical precipitation or filtration. Electrical precipitation alone was employed in the earlier period of the investigation. The equipment was usually operated for periods of one or two hours; therefore samples were representative of average conditions over a short period of time.[1] Starting in 1953, a Staplex high volume sampler, adapted to use flat sheets of fired glass-fiber filter media, was employed. Each sample of dust collected by this equipment was removed from approximately 2000 m^3 of air during a 24-hr period, so that the quantity of lead contained therein represented the average for an individual period of 24 hr.[2]

A third method of collection made use of the Hemeon or AISI smoke sampler. This equipment determined the fluctuations in the concentrations of lead compounds in the air during successive periods of one or two hours.[3] The paper tape used in the smoke sampler is not so efficient a collector of fine dusts as is the electrostatic precipitator or the glass-fiber filter mat, and therefore, the values of samples collected with the AISI instrument were always slightly lower than those obtained by the other two methods. However, the equipment collects large numbers of samples, which show the continuous fluctuations in the relative concentrations of the lead compounds in the air during successive hours of investigation.

Analysis

A spectrochemical method and a chemical method (employing dithizone) have been used interchangeably in this laboratory for many years to determine lead in a wide variety of materials.[4, 5] Numerous samples were analyzed frequently by the two methods in parallel, the differences between individual findings rarely exceeding $\pm 5\%$ of the average of the two analyses. These two methods were used solely for the analysis of dusts collected by electrostatic precipitation and by high volume sampling.

The spots of dust collected on the tapes of the AISI smoke samplers were analyzed by a simplified dithizone procedure in which lead was extracted and determined in a single step.[3, 6] The sensitivity of this procedure was inferior to that of the spectrochemical or dithizone method, so that quantities of lead in the desired range could be determined only with a precision of ± 0.5 microgram.

Results and Discussion

Concentrations According to Population

Samples of atmospheric dust for analysis for lead have been collected in a number of cities at various times. For the purpose of comparing lead in the air of cities of varying population, only those samples were considered which had been collected during comparable years (1954–1955). A total of 1229 samples from 24 cities were analyzed. The various metropolitan centers, classified according to population, are given in Table I. Of the total number of samples, approximately 700 were analyzed for the National Air Sampling Network of the U. S. Public Health Service, and another 280 were collected at two stations in the Los Angeles area, during the "smog" season of 1954. Coverage of the individual cities was not always complete, and the continuity of sampling varied from city to city and station to station, so that the absolute values indicated may not be strictly representative of average conditions in some instances. Nevertheless, the data are sufficiently numerous to indicate trends and the relative order of the concentrations.

The ranges of concentration and the relative frequencies of the findings in

Table I—Classification of Cities by Population

Less Than 100,000	*1,000,000–2,000,000*
Anchorage, Alas.	Cincinnati, Ohio
Frederick, Md.	Houston, Tex.
Ypsilanti, Mich.	Minneapolis, Minn.
	Washington, D. C.
100,000–500,000	*Greater Than 2,000,000*
Chattanooga, Tenn.	Detroit, Mich.
Charleston, W. Va.	Los Angeles, Calif.
Salt Lake City, Utah	New York City, N. Y.
Tampa, Fla.	Chicago, Ill.
Elizabeth, N. J.	Philadelphia, Pa.
	San Francisco-Oakland, Calif.
500,000–1,000,000	
Atlanta, Ga.	
Denver, Colo.	
Kansas City, Mo.	
Louisville, Ky.	
New Orleans, La.	
Portland, Ore.	

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

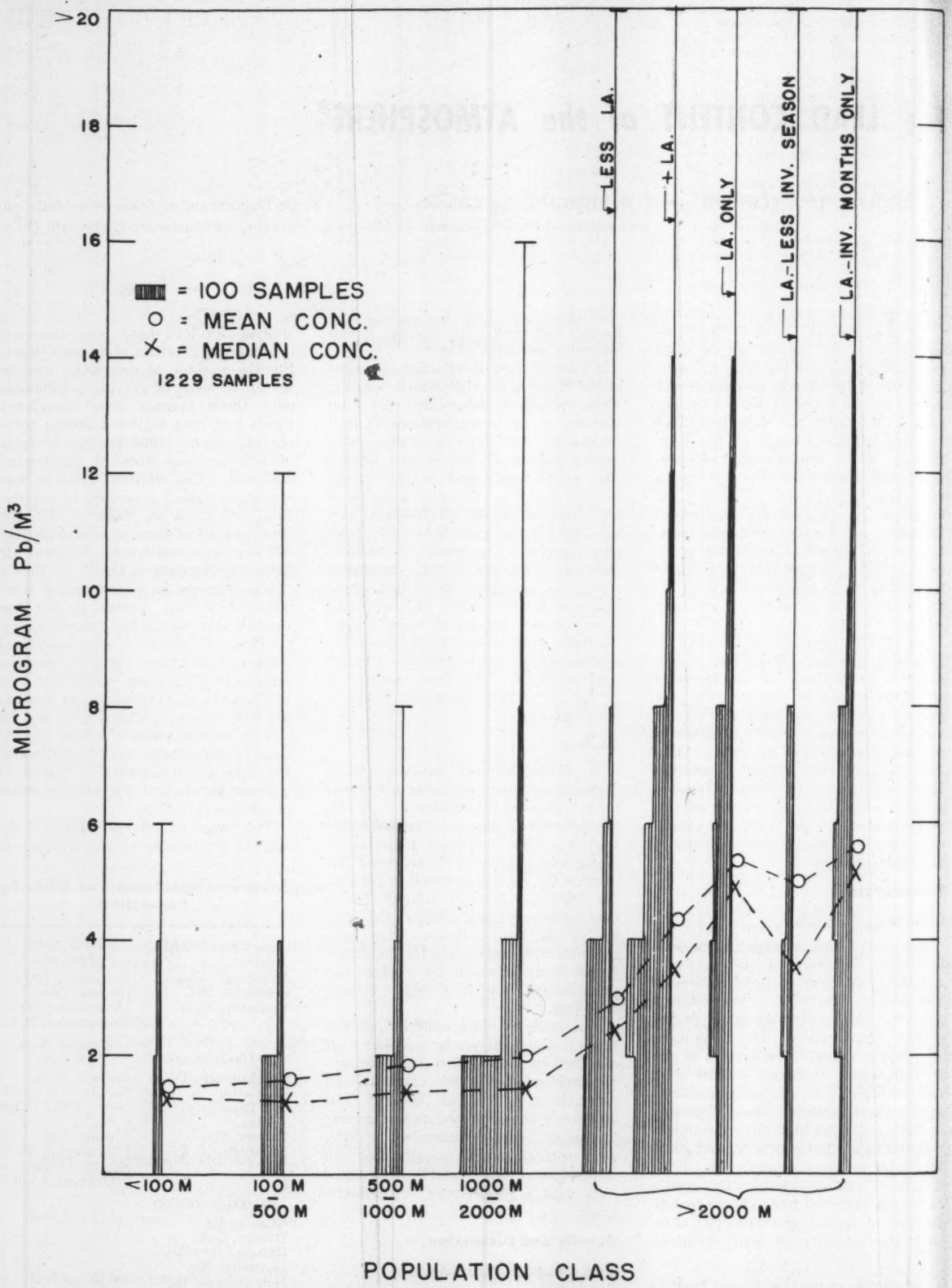

Fig. 1. Bar graph showing ranges of concentration, mean, and median concentrations of lead in various cities grouped according to population. 1954–1955.

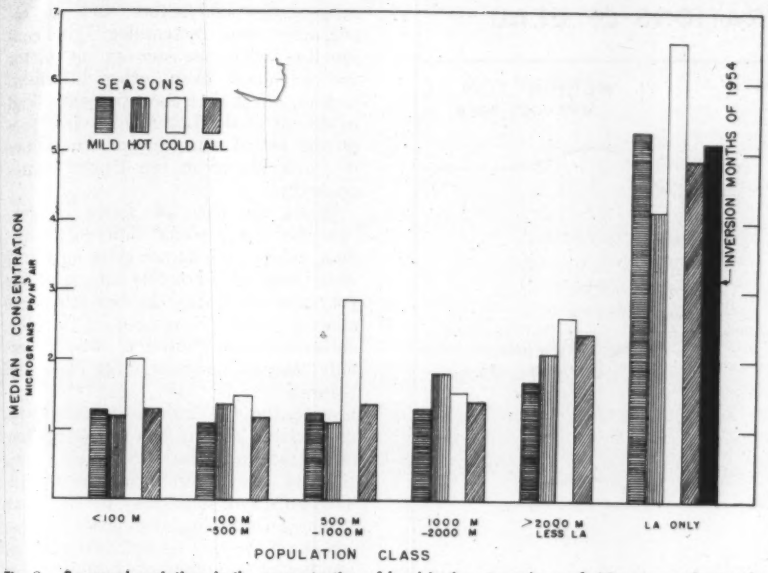

Fig. 2. Seasonal variations in the concentration of lead in the atmosphere of cities grouped according to population. 1954–1955.

various cities, grouped according to population, are tabulated, along with the mean and median concentrations in Table II. The bar graph of Fig. 1 also shows these data. A triangular type of distribution is evident, the skewed character of the distribution being such that a few findings in the upper range contribute undue weight to the average or mean value. The general levels of the concentration of lead in the air are represented better by the median value, which is not influenced, to the same extent as the mean, by a few high values. Therefore, both the mean and the median have been displayed in this illustration. Examination of the data in Table II and Fig. 1 indicates that the ranges of concentration of lead in the air increased with increase in population and that relatively low mean and median concentrations were found in cities up to and including those in the one to two million class. The mean concentrations in the air ranged from 1.47 to 1.99 μg Pb/m³, while the median values ranged from 1.20 μg to only 1.42 μg Pb/m³. When the data for the cities in the greater than two million group were examined, the levels of lead con-

Table II—Frequency of the Occurrence of Certain Levels of Concentration of Lead in the Atmosphere of American Cities of Varying Population

Micrograms Pb/m³ Air	<100 M	100 M −500 M	500 M −1000 M	1000 M −2000 M	>2000 M without LA	>2000 M with LA	LA only	LA Less Inversion Months	LA During Inversion Months
0–1.99	30	64	81	204	86	124	38	10	28
2–3.99	7	7	19	56	82	155	73	19	54
4–5.99	1	2	7	16	23	89	66	7	59
6–7.99	—	—	4	7	3	60	57	10	47
8–9.99	—	2	—	4	4	24	20	2	18
10–11.99	—	1	—	1	1	14	13	—	13
12–13.99	—	—	—	1	2	10	8	—	8
14–15.99	—	—	—	1	—	4	4	1	3
16–17.99	—	—	—	—	—	1	1	—	1
18+	—	—	—	—	2	2	2	1	1
Total	38	76	111	290	203	483	282	50	232
Mean	1.47	1.63	1.81	1.99	2.85	4.28	5.41	4.48	5.62
S. D.	0.95	1.84	1.52	1.97	2.63	0.94	3.42	3.46	3.39
Median	1.30	1.20	1.37	1.42	2.38	3.52	4.91	3.58	5.15

Table III—The Highest Levels of the Concentration of Lead Found in the Air of Certain Cities During the Years Indicated, as Shown by the Analysis of Particulate Material Deposited Throughout Successive Periods of Two Hours on the Tapes of the AISI Smoke Sampler

	(μg. Pb/m³ Air)											
	M–2	2–4 AM	4–6 AM	6–8 AM	8–10 AM	10-N	N-2 PM*	2–4 PM	4–6 PM	6–8 PM	8–10 PM	10–M
Cincinnati, Ohio												
Basin 1955–58	14.6	11.6	11.6	11.1	14.6	6.4	4.6	6.5	8.0	5.5	5.8	11.1
Central 1955–58	20.6	12.5	12.9	12.5	10.4	5.2	7.9	4.8	5.6	4.2	8.7	11.0
Outlying 1958	0.7	0.7	1.1	1.3	2.3	2.1	0.9	0.9	0.9	0.9	0.9	0.9
Los Angeles, Calif.												
Downtown 1954	10.2	12.8	13.4	14.4	16.9	13.0	13.0	7.4	11.3	11.8	15.6	15.5
Pasadena 1954	8.7	7.2	5.8	9.5	9.3	9.4	10.3	9.1	11.9	12.5	13.0	9.8
San Bernardino, Calif. 1954	5.5	8.1	9.0	6.2	6.7	10.2	5.4	3.8	6.1	6.5	6.7	4.1
Washington, D. C.												
Downtown 1954	6.9	6.6	5.7	7.0	11.5	11.2	8.9	8.2	12.3	12.1	8.4	9.8

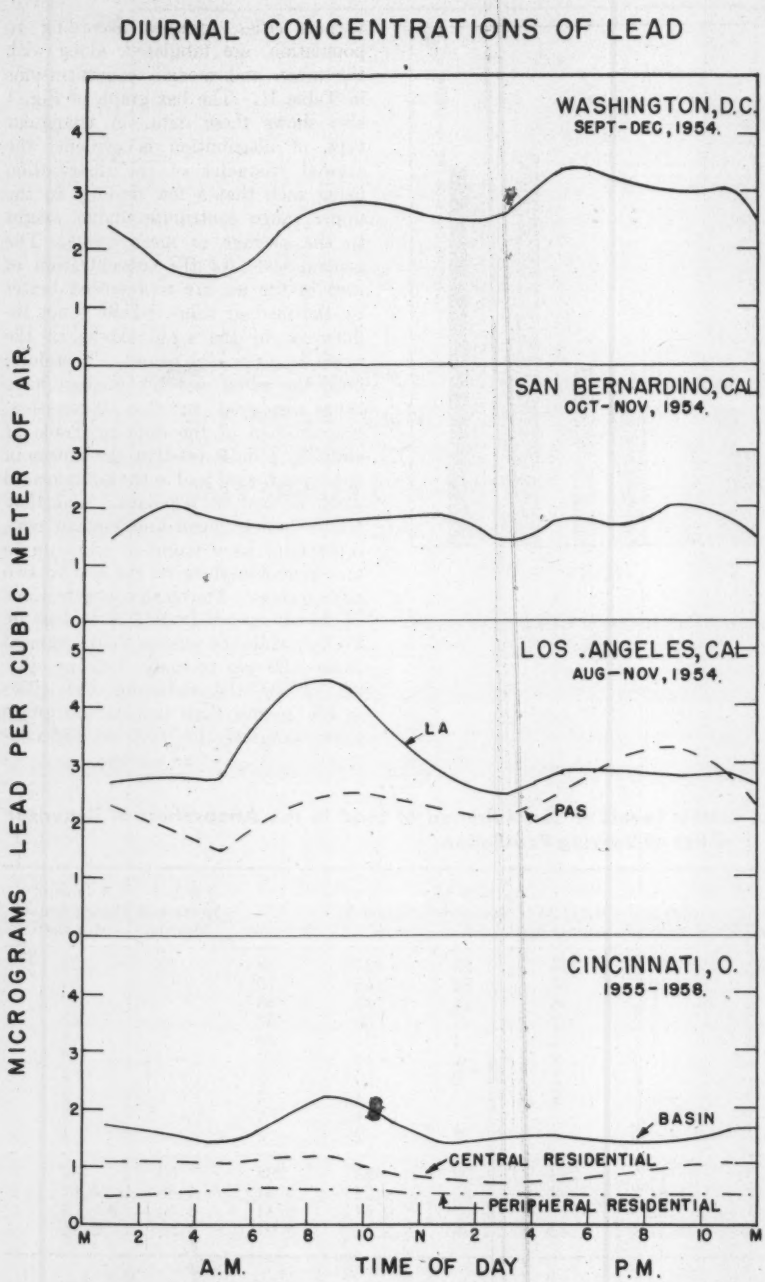

Fig. 3. Average hourly concentrations of lead in the atmosphere at a number of stations in four different communities.

centration were higher, with respect to the range of values, as well as to the mean and median values. Even after the omission of the data obtained in Los Angeles, the difference between the mean and median values for this group of cities and those with population of one to two million were much greater than those which obtained between other adjacent classes of cities.

The concentrations of lead in the Los Angeles area were distinctly higher than those in other cities of comparable population. Even after the exclusion of the analytical results from samples collected in 1954, during the months characterized by frequent inversions, the mean and median levels are almost twice those of the other cities in this group. If those collected in the San Francisco-Oakland area are considered by themselves, the median concentration of lead in the air of this metropolitan area is only 1.50 μg per m^3, a level only slightly greater than the median for the group of cities with one to two million of population. It is evident, therefore, that Los Angeles is unique. Special factors such as topography and meteorology, in conjunction with the density of motor vehicles (and, likely other ill-defined factors) affect the concentration of lead in the air of the Los Angeles area to a greater extent than that of other cities in California or in the United States generally.

When the data of Table II were examined for seasonal differences, median values such as are given in Fig. 2 were obtained. For this bar graph, the year was arbitrarily divided into three seasons, cold (November, December, January, and February), hot (June, July, August, and September), and mild (March, April, May, and October). Except for the group of cities with populations of from one to two million, more lead was present in the air during the cold season than during other times. This apparent trend may be the result of uneven sampling during the various seasons of the year, as well as the limited number of sampling sites employed in some of the cities, so that further work will be necessary to establish its validity.

Diurnal Patterns

Continuous around-the-clock monitoring of the air with the AISI smoke samplers has yielded information on the fluctuations in the concentration of lead during each hour of the periods of investigation in at least four metropolitan areas. These data, plotted in Fig. 3, were limited to single stations in Washington, D. C., and San Bernardino, California, to two stations in Los Angeles, California, and three in Cincinnati, Ohio. Therefore, they should be considered to be representative of the conditions at the individual stations, rather than of the general conditions in these cities. The most distinctive patterns of the fluctuation in the average hourly concentration of lead were obtained at two stations in the Los Angeles area in 1954 during the months in which "smog" occurred frequently. The patterns developed at a station in the basin of the city (LA), and at another in an essentially residential community (Pasadena), show the bimodal character in the fluctuation of the concentrations of lead attributable in all likelihood to the operation of motor cars. The delay, of approximately one hour, in the appearance of the peak of concentration, during the morning in Pasadena, is characteristic of the travel of air pollutants in this area. The higher concentration of lead at the station in Pasadena than at the station in Los Angeles after 6:30 PM may have been due to the decrease in the use of motor vehicles in the commercial area, and the increase in pleasure riding in the outlying suburban areas during the late evening hours.

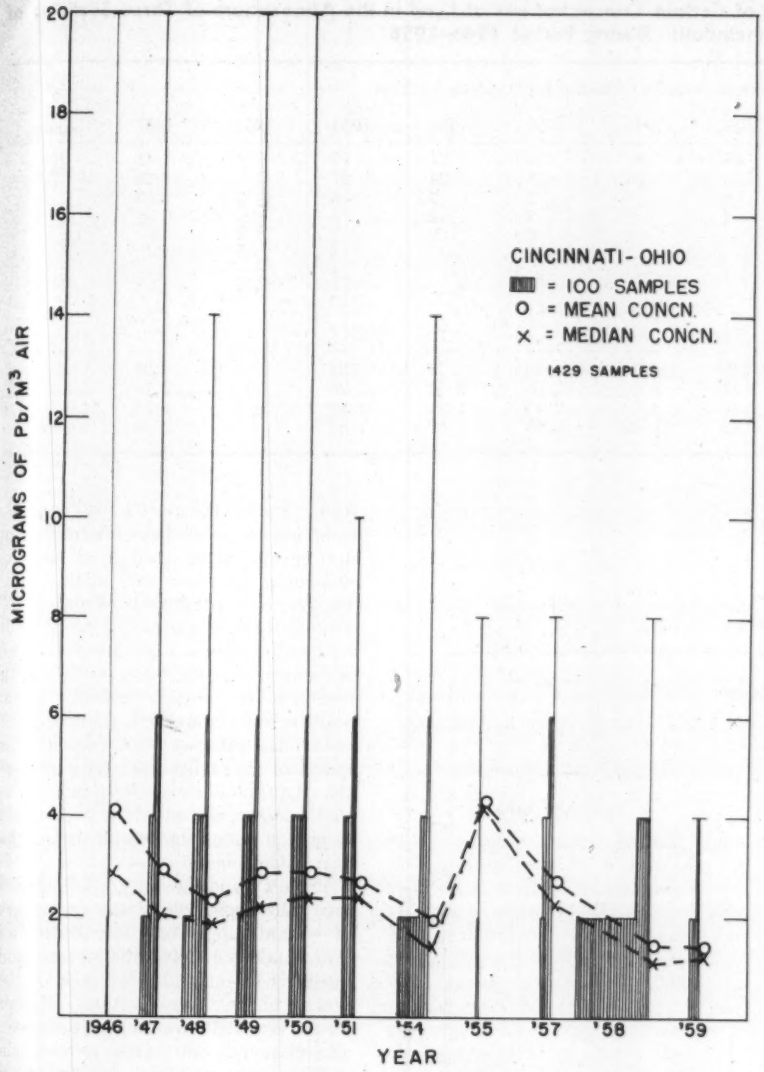
CINCINNATI - OHIO
= 100 SAMPLES
O = MEAN CONCN.
× = MEDIAN CONCN.
1429 SAMPLES
MICROGRAMS OF Pb/M³ AIR
YEAR
1946 '47 '48 '49 '50 '51 '54 '55 '57 '58 '59

Fig. 4. Concentrations of lead in the atmosphere of Cincinnati during the period 1946–1959. (All stations.)

The pattern of the hourly concentrations of lead in the air of a station in downtown Washington, D. C., is also bimodal in character, the higher levels of concentration occurring between 4 and 6 PM (during the late afternoon rush) than at other hours of the day.

In Cincinnati, the patterns of the hourly concentrations of lead reflect the dilution caused by the drift of polluted air from the basin toward the central residential area, and finally toward the peripheral residential centers. The concentration of lead in the air of the basin was appreciably higher than that in the two residential areas. The pattern displayed by the station in the basin was that of an easily distinguishable maximum during the morning hours, coinciding with the maximum movement of motor cars, but the increase in the late afternoon was not so apparent as it was found to be in other cities. In the two residential areas, the concentration of lead remained at practically uniform levels during each hour of the day, with only the faintest suggestion of an increase in concentrations during the peaks of motor car activity.

The maximum concentrations of lead in the air in each two-hour period during the individual investigations are given in Table III. In general, the higher concentrations of lead were found in the air of areas with heavy motor traffic. This is evident from the patterns of the findings in cities in which air was monitored at more than one station. The hours during which the maximum concentration of lead occurred agreed generally with those in which motor traffic was at its height.

Yearly Trends

Since the scope and continuity of air sampling had been maintained more satisfactorily in Cincinnati than elsewhere, only data collected there were employed in the search for yearly trends in the concentration of atmospheric

Table IV—Frequency of Occurrence of Certain Concentrations of Lead in the Atmosphere of Cincinnati. All Stations. 1946–1959

μg. Pb/m³ Air Lead	Numbers of Samples Obtained for Analysis by Years										
	1946	1947	1948	1949	1950	1951	1954	1955	1957	1958	1959
0–1.99	9	70	94	64	56	47	129	6	43	305	33
2–3.99	7	45	62	58	55	44	33	4	33	50	7
4–5.99	2	11	12	8	11	15	8	6	16	6	—
6–7.99	3	6	6	5	6	4	5	2	6	1	—
8–9.99	2	4	1	1	6	2	1	3	—	—	—
10–11.99	—	2	—	3	—	—	1	—	—	—	—
12–13.99	—	—	1	1	—	—	—	—	—	—	—
14–15.99	—	—	—	—	—	—	1	—	—	—	—
16–17.99	—	1	—	—	—	—	—	—	—	—	—
18+	1	2	—	2	1	—	—	—	—	—	—
Total	24	141	176	142	135	112	178	21	98	362	40
Mean	4.08	2.94	2.30	2.86	2.90	2.68	1.90	4.24	2.69	1.36	1.35
S. D.	4.12	3.15	1.79	2.92	2.49	1.82	1.92	2.77	1.82	0.84	0.71
Median	2.86	2.04	1.88	2.24	2.42	2.41	1.38	4.16	2.24	1.18	1.22

Table V—Frequency of the Occurrence of Certain Concentrations of Lead in the Atmosphere of Three Sections of Cincinnati: During Period 1946–1958

Micrograms Pb/m³	Numbers of Samples Obtained for Analysis by Year									
	1946	1947	1948	1949	1950	1951	1954	1955	1957	1958
0–1.99	6	54	68	50	44	37	79		41	305
0–3.99	7	29	38	34	35	24	27		35	50
4–5.99	1	15	6	4	6	9	6		16	6
6–7.99	1	4	4	2	2	2	5		6	
8–9.99	2	6	—	1	2	2	1		—	
10–11.99	—	2	—	1	—	—	1		—	
12–13.99	—	—	1	—	—	—	1		—	
14–15.99	—	—	—	—	—	—	1		—	
16–17.99	—	2	—	—	—	—	—		—	
18+	1	1	1	2	1	—	—		—	
Total	18	113	118	94	90	74	121	—	98	361
Means	3.78	3.30	2.31	2.60	2.56	2.51	2.26	—	2.73	1.34
S. D.	3.15	3.44	2.37	3.00	2.45	1.92	2.41	—	1.79	0.84
Median	2.86	2.17	1.73	1.88	2.05	2.00	1.53	—	2.46	1.08

Downtown only omitted

2 Residential areas only

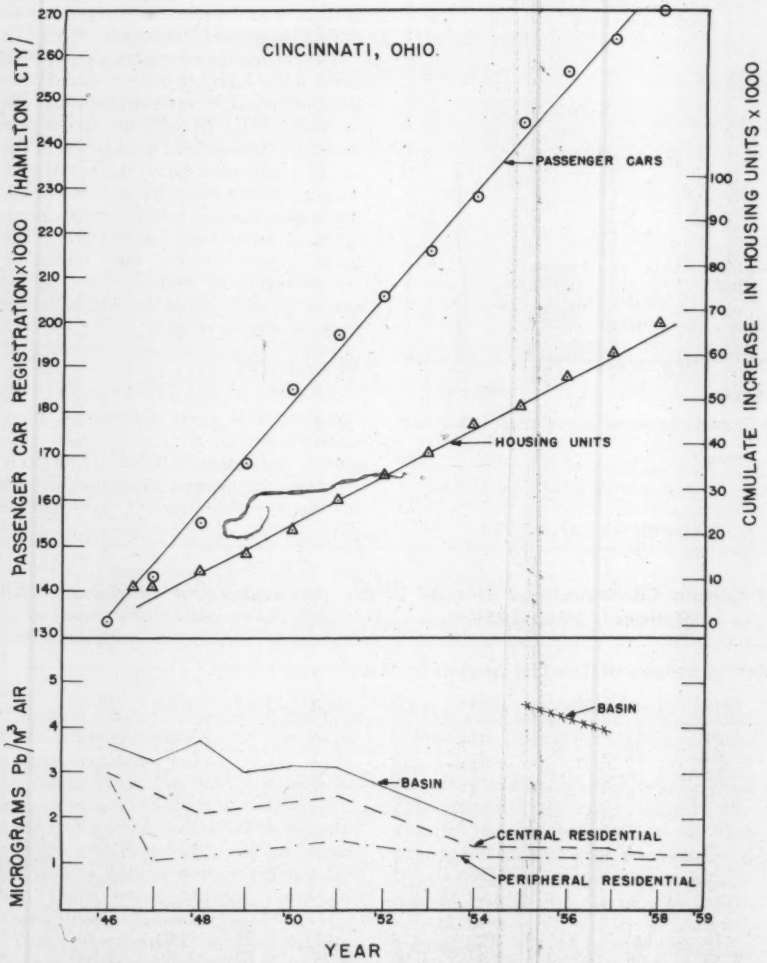

Fig. 5. The median concentration of lead in the atmosphere of various sections of Cincinnati in relation to the registration of automobiles and the construction of new units of housing.

lead. During the period 1946 to 1957, sampling was carried out intermittently and on a random schedule at stations numbering from one as a minimum to 18 as the maximum. From 1957 through 1959, a continuous program of air monitoring was maintained at three stations, one in the basin of the city, a second in the central residential area, and the third in a peripheral residential area. The stations were located on a radius of nine miles from the center of the city and all were in the path of the south and southwest winds which tend to prevail during the greater part of the year in Cincinnati.

Table IV and the bar graph in Fig. 4 give the frequencies of the occurrence of certain ranges of concentration of lead, and the city-wide mean and median concentrations for each of the years under consideration. Except for the year 1955 (when only 21 samples, all collected at one station in the basin of the city, were obtained), there was a continuous downward trend in the median annual concentration of lead found at all of the stations combined during the period 1946–1957. The individual median value for any one year varied only slightly from the median value (2.00 μg Pb/m³) for the entire period. (The data obtained during 1958–1959 were not included in this calculation, because those available during this period were derived solely from two residential areas.) Of interest was the decrease in the range of concentration which had been observed to occur after 1950, when no value exceeded 14 μg Pb/m³ of air. This contrasted with the finding of concentrations greater than 18 μg Pb/m³ of air during four of the five prior years.

An analysis of the data by specific stations involved only those areas of the city in which the sites for the continuous monitoring program of 1957–1959 were located. The findings are given in Table V and in Fig. 5. The atmos-

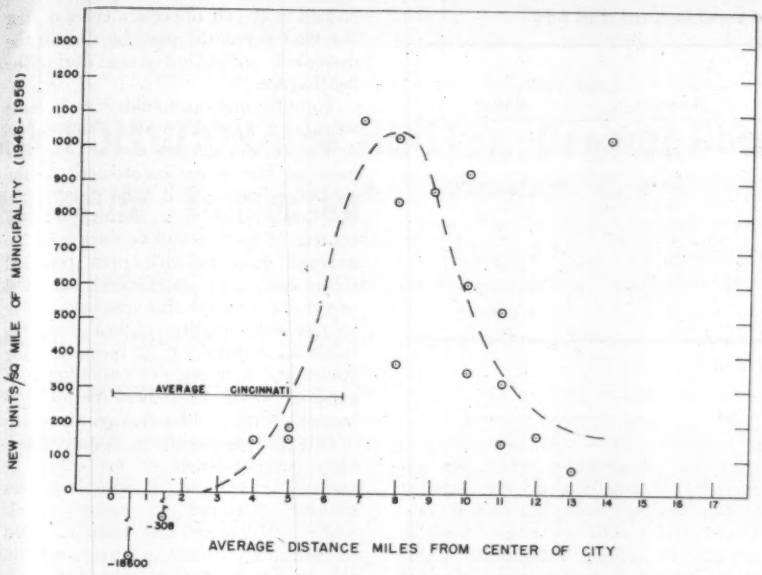

Fig. 6. The rate of construction of new units of housing in certain municipalities north and northeast of Cincinnati.

phere in the basin of the city showed a gradual decrease in its lead content from 1946 to 1954, and then a considerably elevated concentration during the period 1955 to 1957. This increase in the concentration does not apply to the entire basin, for the reason that samples were collected at only one station in the center of the commercial section of the city during those years. However, a generally downward trend is apparent even at this station as well as at the two residential areas during the entire period from 1946 through 1959.

Many speculative predictions have been made concerning the potential increase of air pollutants, particularly of the quantities of lead in the air, as a result of the explosive growth in population and the accompanying increases in various activities in the community. Two factors, the increase in the registration of automobiles and the growth of construction of new housing, both of which will affect appreciably the concentration of atmospheric lead, are shown in the upper section of Fig. 5. Whereas Fig. 5 is concerned only with the registration of passenger cars, Table VI gives also the yearly registration of all petroleum-powered vehicles in Hamilton County. In the entire metropolitan area of Cincinnati, the total registration of petroleum-powered vehicles is probably 30% greater than that in Hamilton County, and it has been estimated by the local Automobile Club that approximately 500,000 motor vehicles enter the area each day. There has been at least a twofold increase in the consumption of motor fuel as a result of the increase in the number of registered vehicles in the area during the years from 1946 to 1958. Accordingly, a significant increase in the concentration of lead in the air might have been expected if it could be assumed that the lead content of motor gasoline had remained essentially

Table VII—Over-all Residential Housing Construction in the Cincinnati Area

	New Units	Area (Sq Miles)	Av. Rate Units/Sq Mile
Communities 7 miles +	11,988	27.608	434.22
Cincinnati up to 7 miles	22,522	81.954	274.81

constant over the years, that the increase in the consumption of leaded fuel had followed the trend shown by the registration of motor vehicles, and that a constant proportion of the lead in the fuel was being emitted into the atmosphere. However, as is seen in Fig. 5, the trend of atmospheric lead has been downward. A number of factors are responsible for this trend. One aspect of the problem relates to the fact that the combustion of gasoline is not the only significant source of lead in the air. The combustion of coal, another source, diminished during this period, and more importantly a sharp limitation of the discharge of smoke and fly ash was achieved by restriction of the sale and use of unsatisfactory types of solid fuels, and by an increasingly effective enforcement of the ordinances relating to the abatement of smoke. Certain other factors have been mentioned in an earlier publication.[7]

Important also is the effect of shifts in population from the core area of the city to outlying areas, and the resulting changes in the pattern of motor traffic in the city. Cumulative construction of new housing, which increases along with the registration of passenger cars, may be used to illustrate this point. Data supplied by a number of local agencies [8, 9, 10] have been used in Fig. 6 and Table VII to show the rate of construction on the outskirts of the incorporated area of the city. It seems

Table VI—Registration of Petroleum-Powered Vehicles in Hamilton County

Year	Passenger Cars	Trucks	Buses	Farm Trucks	Motor Cycles	Dealers' Cars	Public-Owned Vehicles	Total Registration
1946	132,956	16,802	448	1459	1323	344	1736	155,068
1947	142,851	18,413	465	1468	1875	415	1891	167,378
1948	155,203	19,719	494	1523	1650	420	1952	180,961
1949	168,165	20,198	493	1491	1552	369	1987	194,259
1950	185,200	21,769	473	1523	1552	355	1993	212,883
1951	196,569	22,990	536	1514	1500	355	2040	225,773
1952	205,878	23,187	528	1521	1378	373	2085	235,255
1953	216,407	23,876	521	1388	1403	370	2196	246,496
1954	228,447	23,448	496	1345	1280	381	2247	258,009
1955	245,293	24,513	409	1330	1325	415	2340	275,976
1956	256,287	25,163	442	1297	1335	354	2440	287,645
1957	263,476	25,059	462	1239	1413	357	2566	294,900
1958	269,501	24,596	472	1279	1754	360	2667	300,992

Table VIII—Concentration of Lead in Coal and Soil

Material	Number of Samples	Lead, Ppm	
		Average	Range
Domestic Coals	14	10.9	2.0–40.0[a]
Industrial Coals	9	11.5	2.0–24.0
Soil			
Cincinnati Area	6	82.0	16.4–360.0
Avondale	—	28.0	
Hyde Park	2	360.0	
Groesbeck	—	27.2	
Miami	—	16.4	
Bellevue, Ky.	—	43.0	
Hebron, Ky.	—	16.4	
N. and S. America	5	37.2	17.0–64.0

[a] Sample of coke.

that the average rate of construction of new housing units within the city proper averaged about 274 units per square mile over the last 13 years, although the core area, within two miles of the river, suffered a large loss in housing units (Fig. 6). In the area seven or more miles north and east of the center of the basin of the city, the rate of construction was 434 new units per square mile. In order to obtain the over-all city average, shown by the straight line, there must have been a tremendous increase of construction in the areas in the 5 to 6.5-mile radius, so that the bell-shaped curve is probably a good approximation of the rate of growth of areas and adjacent communities. While the rate of construction of new housing units, in the outskirts of the city proper, at a radius of 5 to 6.5 miles had risen sharply, the maximum activity has occurred in communities 7 to 10 miles from the center of the city.

In addition to the spreading of the population, the opening of the core of the city through clearance of substandard housing, and the infiltration of expressways, have modified the traffic patterns in many areas. All of these factors have resulted in a trend toward lower concentrations of lead in the general atmosphere of the city. This trend can be expected to occur in other communities, in which the growth of the population and the multiplication of activities occur within a wide open space which puts little restriction upon lateral and vertical movements of the air.

Sources of Lead

Some considerable portion of the lead in the urban air results from the combustion of leaded motor fuel, but one should not assume that all of it or even the major proportion of it is derived from this source under all circumstances. Hirschler and his associates[11] have shown that only 70 to 80% of the lead in motor fuel is available for emission into the atmosphere, while the remainder is retained in the exhaust system and in the lubricating oils. Under the conditions which tend to prevail in urban automobile traffic (relatively low speed with frequent starting and stopping), 40 to 75% of the lead which is discharged from the motor may be deposited on the walls of the manifold and the more distant parts of the exhaust system. In varying degree, this accumulation will be discharged, much of it in strips and flakes of fairly large size, when the car is operated at the higher speeds of the open highway. Of the total lead exhausted, 27 to 39% has been found to be composed of particles of such size as to settle out of the air rapidly, rather than to remain air-borne. That which is air-borne will be dissipated by local and general currents of air in essentially the same manner and to the same extent as is the carbon monoxide. The extent of the latter under ordinary conditions may be appreciated more fully when one considers the fact that despite the concentration of 5.5 to 7.5% of carbon monoxide in the exhaust of gasoline-powered automobiles, a concentration of carbon monoxide in excess of 0.001% on the sidewalk of downtown streets is unusual.

Other sources of lead in the air include the dusts produced by the industrial processing of material containing lead, the use of lead-bearing insecticides, the weathering and wear of lead-containing products such as paint, solder and bearings, the combustion of coal, and soil which becomes suspended in the air. The averages and the ranges of concentration of lead found in some samples of coal and soil are shown in Table VIII. Inasmuch as 90% of the lead present in coal finds its way into the atmosphere, it is readily apparent that samples of air-borne dusts collected downwind from a large coal-burning installation may contain appreciable quantities of lead. The increased levels of lead in the air of certain cities during the winter months may be due to the increased combustion of coal during the heating season.

Top soil from open fields may become suspended in the air, and in some regions and at certain seasons of the year, this may be the major constituent of the air-borne dusts. Soil from older built-up areas may have an appreciable content of lead, as can be seen from the average value of 360 ppm reported from one area in Cincinnati. The origin of the lead in this area may be due to the accumulation of lead resulting from the weathering or reconditioning (burning, scraping, or abrading) of surfaces which have been painted repeatedly with lead-bearing paints.

It is obvious, therefore, that relatively high concentrations of lead may be present in the air of sampling sites without reference to motor vehicle traffic. Moreover, the data collected in Cincinnati are not in agreement with the predictions that the increased consumption of leaded motor fuel will cause a proportionate increase in the over-all average concentration of lead in the air over our expanding metropolitan centers. In many cities the expansions, with their accompanying changes in traffic patterns and the opening up of central core areas, have tended to promote the dilution of contaminants in the air. The total result may be a lowering of the average concentration of lead in the air, rather than the increase predicted on the basis of simple calculation.

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(*Continued on p. 303*)

AIR POLLUTION *and* HEALTH: *General Description of a Study in Nashville, Tennessee**

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"Take of London fog 30 parts; malaria 10 parts; gas leaks 20 parts; dew drops gathered in a brickyard at sunrise 25 parts; odor of honeysuckle 10 parts. Mix. The mixture will give you an approximate composition of a Nashville drizzle." *A Municipal Report*—O. Henry.

The acute health effects of air pollution have been observed in several, short-term acute episodes that occurred in the Meuse Valley, Belgium, Donora, Pennsylvania, and London, England.[1] More difficult to assess, but of possibly equal importance, are the chronic or long-term effects that may occur as the result of daily, and often lifetime, exposure to sub-lethal levels of contaminants in an urban atmosphere. Mortality studies in this country,[2, 3] and mortality and morbidity studies elsewhere,[4, 5, 6] have demonstrated the likelihood of such effects and the need for further evaluation.

The City of Nashville, Tennessee, was selected for studies designed primarily to develop study methods in the field. The selection of Nashville was based on the belief that it is a community with a chronic, but relatively modest air pollution problem; that the pollution in large measure is caused by a single agent, coal smoke.

Conduct of the Study

The two organizations of the Public Health Service engaged in the field of air pollution research, the Medical Program and the Engineering Program, conducted a joint study. Co-operating were the Tennessee Department of Public Health, the Davidson County Health Department, the Office of the Mayor of Nashville, the Nashville Division of Smoke Regulation, and many other governmental and private agencies and individuals.

Work on the health phase of the study was done largely by the Department of Preventive Medicine and Public Health, School of Medicine, Vanderbilt University, under terms of a contract with the Public Health Service,[7] with some direct operational work being done by Public Health Service staff. A morbidity survey was conducted by the Survey Operations Unit of the University of North Carolina and the North Carolina State University.[8]

Work on the engineering phase of the study was done by Public Health Service staff assigned in Nashville and operating out of the Robert A. Taft Sanitary Engineering Center in Cincinnati. Meteorological studies were conducted by U. S. Weather Bureau staff assigned to Air Pollution Engineering Research at the Sanitary Engineering Center with field operational work being done largely by Public Health Service staff stationed in Nashville. A laboratory and office were established for the engineering phase of the work in quarters leased from the Tennessee Department of Public Health, but some chemical analytical work was done at the Sanitary Engineering Center. Machine data computations were done in part by the State of Tennessee, Department of the Budget, Data Processing Division. Other data processing was done by the Public Health Service in Cincinnati.

Design work of the medical phase of the study began in the fall of 1957, with operational work starting in the spring of 1958. The major morbidity survey was conducted during the first three months of 1959, while various phases of investigative work were completed from time to time during 1958 and 1959. The over-all project was completed in July of 1959.

Design work of the engineering and physical sciences phase of the study began in late 1957. Establishment of aerometric stations and the laboratory was completed by August 1958, while field work was done on a continuous basis from August 1958 through July 1959.

General Description of the Nashville Area

Topography

Nashville is located in Davidson County, in the north-central part of Tennessee, on the Cumberland River. Topographically the city is situated in a basin with hills to the south, west, and north, forming an amphitheater around the city. The hills rise generally to a height of 300 to 400 feet above the mean elevation of the basin, with some higher peaks. The country to the northeast, east, and southeast is more or less open with undulating hills.[9]

Climate

Nashville has a moderate climate with a normal monthly average temperature of 80°F in July, the warmest month, and 40°F in January, the coldest month. Normally there are about 3500 heating degree days per year. Precipitation is ample and fairly evenly distributed throughout the year, while the average annual snow- and sleet-fall of about eight inches is seldom sufficient to interfere with outdoor occupations more than a few days in a season. The area has a moderate

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TABLE 1

SUMMARY OF ROUTINE AEROMETRIC PROGRAM
NASHVILLE AIR POLLUTION STUDY

STATION	NUMBER OF STATIONS	MEASUREMENTS MADE	EQUIPMENT	FREQUENCY OF MEASUREMENT	ANALYSES MADE	ANALYTICAL METHOD	REMARKS
Type I	87	Dustfall	Plastic dustfall collectors - wet bottom	1 - 30 day sample per month	Weight of water insoluble matter	Filter contents of collector, dry, and weigh	Sampling equipment mounted on utility poles
		Sulfur dioxide	Lead peroxide candle	1 - 30 day sample per month	Sulfur trioxide determined as sulfate	Barium chloride method for sulphate; gravimetric	
Type II	25	MEASUREMENTS MADE AT TYPE I STATIONS ALSO MADE AT ALL TYPE II STATIONS					
		Soiling (Suspended particulate)	Sampling train of filter paper, bubbler, trap, orifice, and pump	1 - 24 hour sample per day	Change in light transmission through filter paper	Photometric	Sampling equipment mounted on utility poles
		Sulfur dioxide		1 - 24 hour sample per day	Sulfur dioxide	West and Gaeke method	Laboratory analyses made using Technicon Automalyzer
		Total wind movement	Airways Weather Bureau 2402 Odometer	1 - 24 hour total per day	Total wind movement per 24 hour period	Automatic counter read daily	Sensing elements about 33 feet above ground
Type III	2	MEASUREMENTS MADE AT TYPE I AND TYPE II STATIONS ALSO MADE AT ALL TYPE III STATIONS					Dustfall also analyzed for water soluble; benzene soluble; other combustible; ash
		Suspended particulate	High volume filter paper sampler	1 - 24 hour sample per day	All samples - total weight of particulate matter	Gravimetric	Benzene extracts of many samples fractionated and used for animal studies of possible carcinogenicity
					One sample in ten - further analyses made for total organic; nitrate; and sulfate	As used in U.S. Public Health Service National Air Sampling Network	
		Soiling (Suspended particulate)	AISI strip filter paper sampler	12 - 2 hour or 6 - 4 hour samples per day	Change in light transmission through filter paper	Photometric	2 hour samples in high pollution seasons; 4 hour samples in low pollution seasons
		Sulfur dioxide	Automatic sequential sampler with midget bubblers	12 - 2 hour samples per day	Sulfur dioxide	West and Gaeke method	Atmospheric air filtered before passing through bubbler. Laboratory analyses made using Technicon Automalyzer
Type III M	4	MEASUREMENTS MADE AT TYPE III STATIONS ALSO MADE AT ALL TYPE III M STATIONS					
		Wind speed; wind direction	Beckman and Whitley Model K 100 wind system	Continuous strip chart record	Wind speed - average; maximum; and minimum hourly Wind direction - average; highest veering and backing direction - all hourly	Strip chart observation and data reduction	Sensing elements about 33 feet above ground. Fifth highest veering and backing direction used August 1958 through January 1959
		Temperature; relative humidity	Fries Hygrothermograph Model 594	Continuous strip chart record	Average hourly values taken from charts	Strip chart observation and data reduction	Instrument in Weather Bureau Cotton Region type shelter
Type III C	4	MEASUREMENTS MADE AT TYPE III STATIONS WERE MADE AT ALL TYPE III C STATIONS EXCEPT THAT TWO-HOURLY SULFUR DIOXIDE MEASUREMENTS WERE NOT MADE					
Type III X (Central Station)	1	MEASUREMENTS MADE AT TYPE III STATIONS MADE ALSO AT THE TYPE III X STATION					
		Sulfur dioxide	Thomas Autometer	Continuous strip chart record	Sulfur dioxide	Change in electrolytic conductivity of hydrogen peroxide - sulfuric acid absorbing solution	
		Nitrogen dioxide	Kruger Model 73 Atmosphere Analyzer	Continuous strip chart record	Nitrogen dioxide	Automatically recorded colorimetric analysis based on method described by Saltzman	Nitric oxide channel of recorder not operated successfully
		Oxidant			Oxidant	Automatically recorded colorimetric analysis based on neutral KI reaction	
		Carbon monoxide	N.S.A. Luft type non-dispersive infrared analyzer	Continuous strip chart record	Carbon monoxide	Absorption of infrared radiation converted to electrical output signal	
		Suspended particulate matter collected	Positive displacement pump; sheets of membrane filter media	Sampler run continuously. Each filter used 2 - 4 weeks	Particulate matter mechanically removed for use as collected		Collected material used for animal studies of possible carcinogenicity
Cordell Hull Building	1	Visual range	Human observer	0900 and 1500 CST daily		Visibility of certain objects at known distances away was noted	
		Photographs	Camera	0900 and 1500 CST Daily		Appraisal of degree of haze as shown on pictures	Picture taken in three compass directions
		Incoming radiation	Instrument Corp. Actinometer	Continuous strip chart record	Average hourly total incoming radiation	Instrument operates on a differential heating principle	
Television Tower	1	Upper air wind speed; wind direction	Bendix-Friez Aerovane	Continuous strip chart record	Same as at Type III M stations	Same as at Type III M stations	Sensing units at 251.5 and 501.5 feet above ground - recorder at ground level
Downtown park area	1	Net radiation	Suomi Economical Net Radiometer	Four times per minute-recorded	Net radiation. (Difference between incoming solar and sky radiation and outgoing terrestrial radiation)	Output of thermopiles recorded	Located in small park area near downtown area near Cordell-Hull Building
U.S. Weather Bureau Airport Station Berry Field	1	Upper air winds	Pilot balloons and rawinsonde	4 per day at 0600; 1200; 1800; and 2400 CST	Wind speed and direction at specified levels		Pilot balloons at 1200 and 2400 CST Rawinsonde at 0600 and 1800 CST
		Sunshine	Marvin Sunshine Recorder	Continuous strip chart record	Minutes of sunshine each hour	Instrument is a differential air thermometer	
		Upper air temperature; pressure; relative humidity	Radiosonde units	0600 and 1800 CST daily	Temperature, relative humidity, and pressure in upper air		Other measurements usually made at USWB first order stations are available

frequency of thunderstorms. Prevailing winds are from the south in all months except September when north winds prevail. Monthly average wind speed ranges from 6.6 mph in August to 10.4 in March.[9]

The People of Nashville

The City of Nashville, in 1958, had a population of about 167,000. The metropolitan area of Nashville (all of Davidson County) had a population of about 375,000. About one-third of the city residents of Nashville are Negro, and there are few foreign-born. The white population had no unusual mortality experience except for a slightly increased death rate due to parasitic and infectious diseases of the gastro-intestinal tract, to homicide, and to senility and other ill-defined causes.[10]

Dispersion of Pollution

During most of the year, meteorological conditions are generally favorable for dispersion of pollutants. However, there are occasions, especially during the fall and early winter, when the atmosphere is unable to disperse airborne materials adequately, and pollutants tend to accumulate over the city. There are many mornings and evenings when a pall of pollutants can be seen.[11] Visual observations indicate that considerable variations in pollution levels occur within the Nashville area. Data presented by Korshover[12] indicate that Nashville is located in an area in which the weather is relatively often dominated by stagnating anticyclones which persist for four days or more. Such conditions lead to accumulation of pollutants. In Nashville, stagnating anticyclones occur most frequently in October.

Air Pollution in Nashville

Nashville has had a long history of major smoke problems. A report dated 1935 stated[13] "Few cities in the United States have a greater smoke nuisance to contend with during the winter months than Nashville. It has been so dense on occasions that the visibility was reduced to zero, the sun's disc invisible from street level, and street and automobile lights kept burning until after 10 AM, although at the same time just outside the smoke area the sky was brilliantly clear." The smoke problem is not as severe now as it was years ago, but smoke and other air pollutants still are a matter of considerable concern. Limited air sampling done in 1957 indicated that pollution due to suspended particulate matter was about equal to that in other cities of comparable size.[14]

Sources of pollution include space and water heating plants, industrial plants, transportation equipment, and refuse burners. Energy for domestic space and water heating is currently derived about 35% from bituminous coal, 40% from natural gas, 15% from electricity, and some oil and wood. A considerable amount of coal is used by commercial and industrial plants, along with natural gas and oil. Natural gas usage by domestic consumers increased almost fourfold from 1948 to 1958. Commercial and industrial use of natural gas increased almost eightfold in the same period, indicating a substantial change of fuel from coal to gas by these two types of consumers, as well as expanding human activity. Rubbish burning on domestic premises is a widespread practice. Refuse is also disposed of in sanitary landfills. Leading industries include printing, chemicals, food products, fabricated metals, and leather. Individual industrial plant emissions which have been recognized as problems in Davidson County include smoke from fire-cleaning of scrap automobiles; dust from crushed limestone, cement, and brick works; acid, dust, ammonia, and fluorides from fertilizer and phosphate plants; foundry dust and fumes; acids and lead from battery plants; acids and alkalies from electroplating; carbon disulfide and hydrogen sulfide from a rayon plant; and various others.[11] Transportation equipment includes some 132,000 motor vehicles (Davidson County, 1956) which consume about 300,000 gallons of gasoline per day; locomotives (all diesel) operating on three railroad lines; buses; trucks; and some river vessels. All of these emit pollutants to the atmosphere.[11]

Medical Phase of the Study

Four separate but related medical studies were conducted: (*1*) a morbidity survey, (*2*) a mortality survey, (*3*) a cardio-respiratory disease study, and (*4*) an anthracosis study.

The Morbidity Survey

Objectives

1. To obtain general and specific morbidity data of residents of the City of Nashville and its suburban fringe.
2. To determine whether there is an association between any morbid conditions and exposure to air pollutants.

Plan of the Study

A questionnaire was prepared and pretested in the field in a distant part of the county that was not to be included in the final survey. The questionnaire was designed to provide general as well as specific information concerning the occurrence of morbid conditions and disability on the day of the interview, during the previous two weeks, the previous year, and in the past. In most cases, the respondent was the wife of the head of the family who furnished information for all other members of her family. A probability sample of approximately five percent of the occupied dwellings in the study area was selected. Interviewing began in January 1959 and was concluded in March.

In order to provide a check on validity of information obtained during the interview, 106 families comprising 377 individuals were examined by a physician within a short time after the interview. Examinations were done by experienced internists and pediatricians in special night clinics organized for the purpose at Vanderbilt University Hospital. Complete histories were taken and physical examinations performed on each individual. In addition, the following screening procedures were done: complete blood, urinalysis, chest film, EKG, Wasserman, and pulmonary function tests. Papanicolaou smears were done on married females.

Other verification of illness and disability reported on interview was obtained by securing information from medical records of doctors and hospitals for reported attended-illness of a 10% sample of the survey group.

Analysis of Data

Data will be analyzed to show differences in occurrence of specific morbid conditions in different areas of the city, by such variables as age, sex, race, and socio-economic status. Air quality data will be used to determine whether an association can be shown between degree of atmospheric pollution and the frequency of any morbid conditions.

The Mortality Survey

Objectives

1. To determine mortality rates for specific causes by census tracts for residents of the Standard Metropolitan Area of Nashville.
2. To study the relation between these death rates and demographic, social, and economic data for these census tracts.
3. To determine whether deaths for specific causes vary significantly with residence in areas of relatively high or low atmospheric pollution.

Plan of the Study

Approximately 25,000 deaths were reported in Davidson County including Nashville from 1949 to 1956. This span of years was selected because it is the period of time between revisions of the *Manual of the International Statistical Classification of Disease, Injuries, and Causes of Death*. Data obtained from death certificates in-

IND. NO._____	ASTHMA CALENDAR				REPORT NO._____		
DATE	MON. ____	TUES. ____	WED. ____	THUR. ____	FRI. ____	SAT. ____	SUN. ____
TIME ATTACK STARTED							
TIME ATTACK ENDED							
MEDICINE TAKEN	YES ☐ NO ☐	YES ☐ NO ☐	YES ☐ NO ☐	YES ☐ NO ☐	YES ☐ NO ☐	YES ☐ NO ☐	YES ☐ NO ☐
PLACE OF ATTACK							
NO ATTACK							

C-R Form 2

Fig. 1. Weekly report card used by asthmatic patients in cardio-respiratory disease study.

IND. NO._____	C-R CALENDAR				REPORT NO._____		
DATE	MON. ____	TUES. ____	WED. ____	THUR. ____	FRI. ____	SAT. ____	SUN. ____
BETTER							
SAME							
WORSE							
MUCH WORSE							

C-R Form 4

Fig. 2. Weekly report card used by patients (other than asthmatics) in cardio-respiratory disease study.

cluded age, sex, race, marital status, residence at time of death, occupation and industry, and immediate, contributory, and underlying causes of death. For purposes of this study it was necessary to allocate the residence at time of death to a specific census tract and planning unit. Accordingly a coding guide was prepared which listed by number the census tract and planning unit for every official street in the county except for nontracted areas.

Since the only population data available from the Bureau of the Census dated back to 1950, it was necessary to estimate the total population for the study period. Data from the 1950 census,[15] Nashville-Davidson County Advance Planning Commission estimates for 1958[16] in conjunction with data from the morbidity survey, and the mortality statistics themselves, were used to estimate the base.

Analysis of Data

Specific causes of death by age, sex, and race will be determined for each census tract. The census tracts will be grouped into five socio-economic classes based on median rental from data obtained during the morbidity survey and the 1950 census. Mortality rates for specific causes will be analyzed in relation to air quality data.

Cardio-Respiratory Disease Study

Objectives

1. To determine whether individuals known to have a specific cardio-respiratory disease show variation in frequency or severity of their attacks depending on diurnal or seasonal variation in their exposure to environmental air pollutants.
2. To determine whether the course of disease in individuals known to have a specific cardio-respiratory disease differs according to their residence in areas of relatively high or low air pollution.

Plan of the Study

One hundred twenty-three patients, children and adults, were selected from the Vanderbilt University Hospital Out-Patient Department clientele and from among private patients of local physicians. Included in the study were 49 adults and 35 children with bronchial asthma, and 39 adults with other cardio-respiratory diseases. All patients were given a complete physical examination after a detailed history was obtained. All were given periodic pulmonary function tests. The asthmatics were asked to mail a weekly report card (Fig. 1) with information concerning number of attacks each day, time of onset, duration, place of occurrence, and medication used. The other patients on the panel were asked to mail a different report card (Fig. 2) indicating their status each day as either the "same," "better," "worse," or "much worse" than usual.

Pollen counts were made seasonally to provide data needed for control of an important variable in the occurrence of asthmatic attacks.

Analysis of Data

The frequency of asthmatic attacks and the daily status change of the non-asthmatic panel patients will be compared with meteorological variations and changes in concentration of air pollutants. The residence of each patient with respect to local environmental air pollution will be studied in relation to the course of disease.

Anthracosis Study

Objectives

1. To determine whether residents of Nashville examined at autopsy have a greater degree of anthracosis than nonresidents.
2. To determine whether the degree of anthracosis in Nashville residents varies according to the area of their residence in the city.
3. To determine whether anthracosis in Nashville residents is related to length of their residence in the city.
4. To determine whether anthracosis is commonly associated with any other pulmonary or any cardiac pathology.
5. To determine whether anthracosis is identified with any specific symptomatology.

Plan of the Study

Data were obtained on 641 autopsies done at Vanderbilt University Hospital between 1953 and 1956 inclusive. Consecutive autopsies were studied with the exception of individuals under five years of age and a relatively small number of cases in which there were either no lung sections available for study or for which there were insufficient clinical data. This study was a completely "blind" investigation in which various categories of data were independently obtained in order to guard

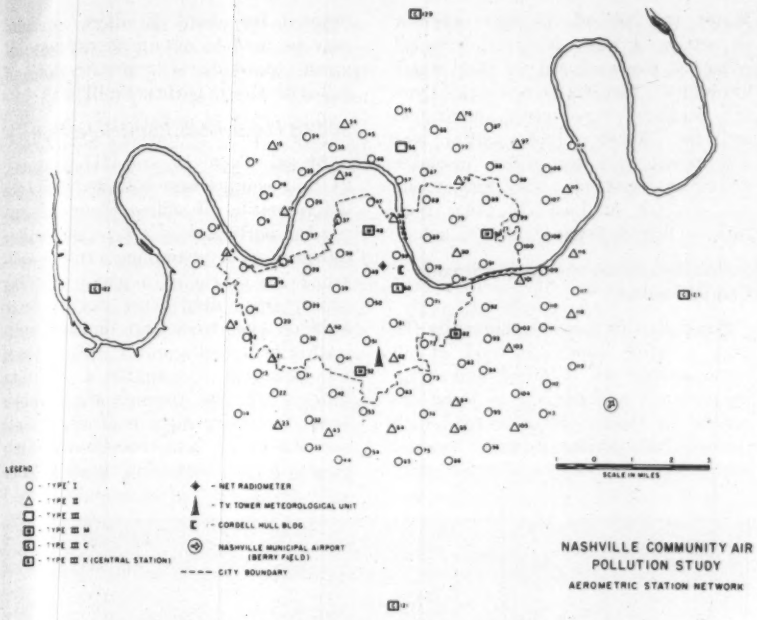

Fig. 3. Aerometric station network for Nashville community air pollution study.

against introduction of bias. The degree of anthracosis was evaluated with the help of standards prepared by Dr. John L. Shapiro, Professor of Pathology of Vanderbilt University School of Medicine. The chief anatomical cause of death and other cardio-respiratory pathology found at autopsy were obtained directly from the official autopsy protocols of Vanderbilt University Hospital. Cardio-respiratory disease symptoms that were present during terminal illness and at any previous time were obtained from the history recorded in the Vanderbilt University Hospital charts. Residence data and occupational data for as many as 20 years before death were obtained for Nashville residents from city directories. All others were grouped as out-of-city residents and no further effort was made to obtain residence or occupational data.

Analysis of Data

Variations in degree of anthracosis will be determined in the autopsy group according to age, sex, race, and residence factors. Comparisons will be made of the degree of anthracosis with frequency of cardio-respiratory symptoms and with occurrence of cardio-respiratory pathology. Among residents of Nashville a comparison will also be made of the degree of anthracosis and residence in an area of high or low air pollution.

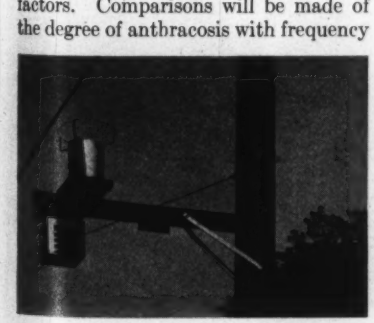

Fig. 4. Type I aerometric station.

Engineering and Physical Sciences Phase of the Study

Objectives

Provisions were made for operational testing of various field study design factors and means of conducting air pollution field studies. These objectives were interwoven with the mission of providing air quality data for use in medical studies. Objectives were as follows:

1 Determine representativeness of air quality data with respect to number and location of sampling stations, sampling frequency, and sampling time, all as related to various uses of the data.
2 Make operational evaluations of the study design employed; of analytical methods for determining pollutants; and of equipment and procedures used.
3 Study dispersion of air pollutants arising in an urban area as related to source distribution and meteorological parameters and evaluate methodologies for such studies.
4 Determine public opinion regarding air pollution as related to pollution levels and population characteristics.
5 Determine the extent to which radiosonde data from the U. S. Weather Bureau airport station can be used to classify stability of the lower atmosphere over the urban area into broad classes of "stable" and "unstable."
6 Determine relationships between air pollution concentrations at a selected station and meteorological parameters measured at the same station, and at different stations.

Fig 5. Type II aerometric station.

Aerometric Station Network

Aerometric stations were established at 123 sites in the Nashville area. Of these, 119 were located at the intersection of lines forming an equilateral triangle grid pattern in the urbanized part of the area. These stations covered an area about nine miles in diameter, centered around Ninth and McGavock Streets in downtown Nashville (station 60). Control stations were located in the four cardinal compass directions from the central station and about three miles beyond the station network (Fig. 3). Stations were placed about 0.87 mile apart. The triangular grid was selected in preference to other patterns in order to reduce the number of stations needed to provide a sampling site within one-half mile or less of all points in the area. This distance was selected on the basis of some experience with studies of relationships between air pollution and health conducted in England, but must be considered as a rather arbitrary judgment based on limited factual data.

The precise placement of aerometric stations was dependent upon availability of access streets, electric power (at two types of stations), and freedom from obstructions to air movement required for use of certain equipment. At stations equipped with wind measuring instruments it was necessary to give consideration to topographical features near these stations and to have a utility pole upon which to mount wind sensing elements. In some cases these various requirements made it necessary to locate stations some distance away from the corners of grid triangles, and in a few cases to deviate from uniform spacing.

The aerometric network consisted of three general types of station with

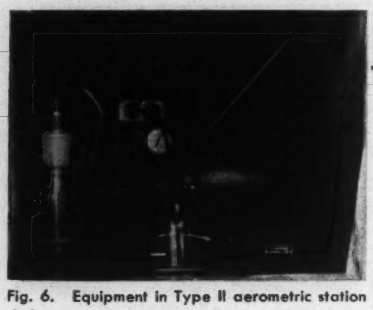

Fig. 6. Equipment in Type II aerometric station shelter.

one (Type III) being further divided into four sub-types. There were several additional stations for specific measurements. The urbanized area was covered in a reasonably uniform manner with respect to all three types of station (Fig. 3). Measurements at Type I stations were simple, consisting of dustfall collection and indication of sulfur dioxide by the lead peroxide candle method. Type II stations were provided with the same equipment as Type I stations, and in addition were equipped to obtain a volumetric measure of sulfur dioxide and soiling by suspended particulate matter (one 24-hour filter paper sampler per day for each). Type II stations were equipped with a wind odometer to provide a measure of total air movement for each 24-hour period. Type III stations were equipped with all the same apparatus as Type I and Type II stations, and in addition, other apparatus. A description of all activities conducted on a routine basis is summarized in Table I.

At Type I stations equipment was mounted on a cross arm attached to a utility pole at about 11 ft above ground (Fig. 4). At Type II stations, equipment was mounted on a cross arm attached to a utility pole, with some of the equipment housed in a ventilated cabinet, also at about eleven feet above ground. The sensing element for a wind odometer was mounted on top of the pole with the counter located in the cabinet (Figs. 5 and 6). At Type III stations, lead peroxide candle and dustfall equipment were mounted in the same manner as at Type I and II stations. Other equipment was housed in a walk-in shelter (Fig. 7). Sensing elements for wind measuring equipment were mounted on top of the utility pole, with registering instruments housed in the shelter.

Methods for Routine Aerometric Measurements

Dustfall

Settled dust was collected by use of plastic wastepaper containers. They were $10^3/_4$ in. high, $7^3/_4$ in. in diameter at the top, and $6^3/_8$ in. at the bottom. Water was placed in each collector on setting it out. Material from all collectors was analyzed for total water insolubles. Samples from the 11 Type III stations were given additional analysis. Water soluble matter was determined and the water insoluble matter was further analyzed for benzene solubles, for combustibles other than those soluble in benzene, and for ash.

Sulfur Dioxide by the Lead Peroxide Candle Method

Sulfur dioxide was determined by the lead peroxide candle method at all sampling stations. Methods and equipment used[17] were similar to those described by Parker and Richards[18] with modifications developed by the Tennessee Valley Authority. Candles were exposed for about 30 days. Results may be used to obtain an estimate of mean atmospheric concentration of sulfur dioxide in parts per million.[19]

Soiling (Suspended Particulate Matter)

At all Type II and III stations, 24-hour samples were collected daily for determination of soiling power of suspended particulate matter (and sulfur dioxide). The sampling train consisted (in order) of a glass sampling probe, strip filter paper holder, large bubbler, glass wool trap, limiting (critical) orifices, and a pump. The system was arranged to provide a constant flow of 0.5 lpm through the bubbler (used for sulfur dioxide measurement) and 0.5 to 1.5 lpm through the filter paper, the rate depending on air volume

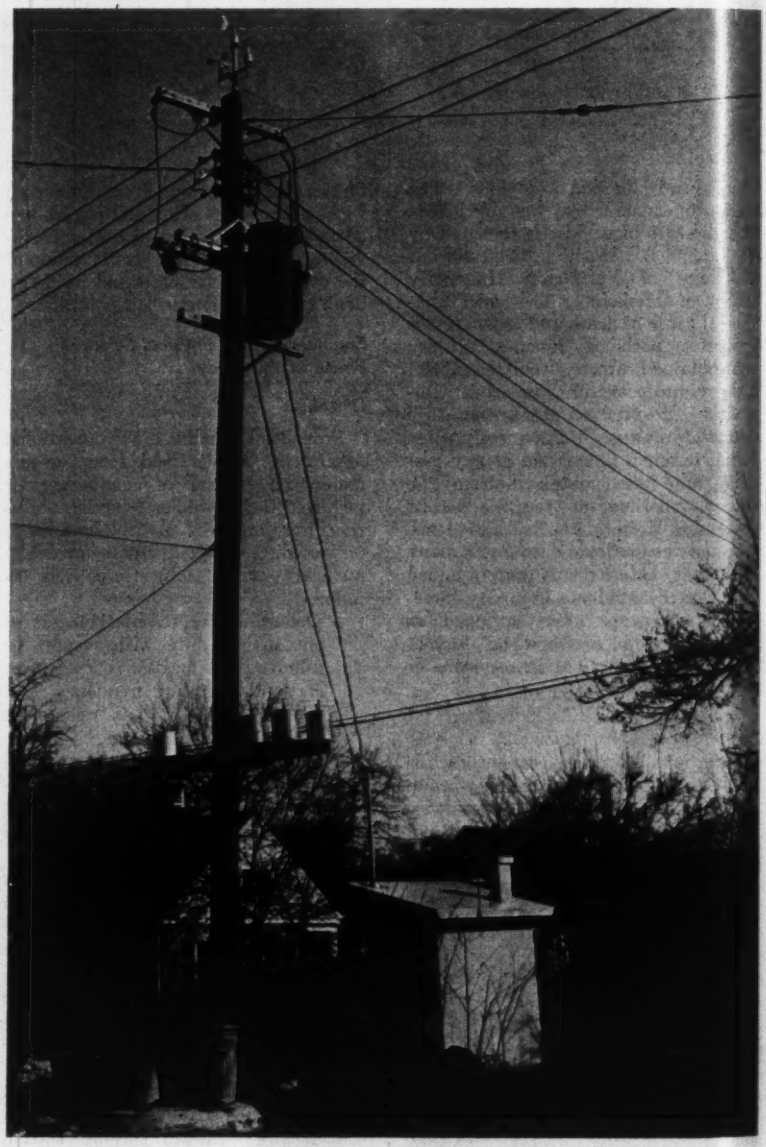

Fig. 7. Type III M aerometric station.

needed to obtain a sample of suitable optical density. The filters were short pieces of strip filter paper usually used in AISI type samplers (Whatman No. 4). Evaluation of the amount of suspended particulate matter collected was done by measuring light transmission through the sample spot and through clean filter paper adjacent to the sample spot and noting the difference. A spot evaluator usually used for AISI strip filters was employed.[20]

At all Type III stations, soiling power of suspended particulate matter was determined also on a two-hourly basis in high pollution seasons and on a four-hourly basis in low pollution seasons. AISI type strip filter paper samplers were used with Whatman No. 4 filter paper.[21, 22] Sample spots were evaluated by measuring light transmission through the sample spot and a clean place on the filter, and noting the difference. A manual spot evaluator[20] and an automatic spot evaluator with a digital recorder[23] were used. A sampler calibration technique and method of computation were used which minimized possible errors in results.[24]

Volumetric Sulfur Dioxide Determination

Three different classes of volumetric sulfur dioxide determination were made. These were 24-hourly and two-hourly samples collected and analyzed by a method adapted from a procedure described by West and Gaeke[25] and a Thomas Autometer.[26, 27] At all Type II and III stations, 24-hourly samples were collected in large fritted bubblers. The bubblers were part of the 24-hourly sampling train described above. At Type III stations (Type III C excepted) 12 two-hourly samples were also collected each day, using midget fritted bubblers with automatic sequential samplers.[28] Analytical procedures followed recommendations of West and Gaeke except that a 0.005% rosaniline hydrocholoride—5% hydrochloric acid mixture was used instead of 0.04%—6%. The modification was necessary[17] to overcome difficulties encountered in use of the automatic analytical device[29] employed in analysis of all bubbler-collected samples of sulfur dioxide. The Thomas Autometer was operated continuously at the Type III X (central) station.

Suspended Particulate Matter

High volume filter paper samplers[30] were operated at all Type III stations, collecting one 24-hour sample per day, using eight by 10 in. sheets of flash-fired glass fiber filter web.[31] Samplers were placed with the filter horizontal at the lower end of a vertical duct which extended through the roof of walk-in shelters.

Total weight of particulate matter collected was determined gravimetrically. In addition, the two samples indicating the highest concentration of particulate matter in air, and the one sample indicating the lowest concentration for each calendar month at each of 11 stations (total of 33 samples per month) were analyzed for total organic matter, nitrates, and sulfates. Analytical procedures were those employed in the Public Health Service National Air Sampling Network.[14]

High volume filters from urban stations (all Type III stations except III C) not used for the foregoing analyses were extracted with benzene to obtain organic matter from them. Part of the total organic extracts were sent to the National Cancer Institute for animal studies of possible carcinogenicity. The rest of the organic extracts were separated into three classes of compounds: (*1*) aromatic hydrocarbons; (*2*) aliphatic hydrocarbons; and (*3*) oxy-neutral compounds. The latter two fractions were used at the University of Southern California by Dr. Paul Kotin for animal studies of possible carcinogenicity. The aromatic hydrocarbons were sent to the National Cancer Institute for similar use.

Suspended particulate matter was also collected at station III X from September 1958 through July 1959 using membrane filters.[32] Each filter was used for four weeks unless particulate matter collected caused excessive pressure drop across the filter. In such cases, a shorter time (two to four weeks) was used. Filters were sent to the National Cancer Institute where particulate matter was removed mechanically and used for animal studies of possible carcinogenicity. This technique made particulate matter available which had not been altered by chemical extraction or separation nor contaminated with filter media.

Nitrogen Dioxide, Oxidant, and Carbon Monoxide

Nitrogen dioxide and oxidant concentrations in the atmosphere were measured continuously at station III X (central station) using an automatic recording instrument.[33] The three channel instrument is designed for measurement of nitric oxide also, but this part of the instrument was not used. Determination of nitrogen dioxide is based on a method described by Saltzman.[34] Oxidant determination by the instrument makes use of the neutral potassium iodide method and is based on a design by Littman and Benoliel.[35]

Atmospheric carbon monoxide was continuously measured and recorded at station III X using a Luft type non-dispersive, selective, infrared analyzer.[36]

Photographs Depicting Visibility and Visual Range Observations

Photographs were taken routinely to provide a record of the appearance of the air over Nasbville and to develop a relationship between appearance of the air mass and pollution levels. Photographs were taken in three directions (north, east, and west) from the roof of the Cordell Hull Building (about 130 ft above ground) at 0900 and 1500 CST each day. Visual observations were made of sky conditions (cloudy, clear, etc.) at the time pictures were taken.

Observations of visual range were also made from the roof of the Cordell Hull Building at 0900 and 1500 CST each day. Visual range was recorded as the number of miles from the point of observation to the farthest away of certain landmarks which could be seen by the observer. The technique was patterned after that used by the U. S. Weather Bureau.[37]

Wind Measurements (Surface)

Total wind movement for each 24-hour period was measured at all Type II and III stations using wind odometers.[38] A three-cup anemometer was mounted on top of utility poles at about 33 ft above ground.

Wind direction and velocity recording units[39] were operated at Type III M stations. Three-cup anemometers with wind vanes were mounted on top of utility poles along with wind odometers at about 33 ft above ground.

Wind speed and direction data from the U. S. Weather Bureau Station at Nashville Municipal Airport (Berry Field) were obtained. Instruments in use are standard U. S. Weather Bureau type and sensing elements are mounted at about 43 ft above ground.

Wind Speed and Direction (Upper Air)

Two wind speed and direction transmitters were installed on the WSM-TV tower at about 251 and 501 ft above ground, with continuous dual recorders at ground level.[40] Transmitters were mounted on arms extending out about four feet from a corner of the tower.

Four upper air wind observations are made daily by the U. S. Weather Bureau Station at Berry Field. These are made at 0600 and 1800 CST using standard Weather Bureau rawinsonde equipment, and at 1200 and 2400 CST using pilot balloons (pibals). Wind speed and direction are determined at specified levels from the surface to the elevation of the balloon at termination of the flight.

Temperature, Relative Humidity, and Barometric Pressure

Temperature and relative humidity

were continuously recorded at Type III M stations using recording hygrothermographs.[41] Instruments were housed in standard U. S. Weather Bureau, Cotton Belt Region, thermometer shelters. Wet- and dry-bulb temperatures were measured each hour by the U. S. Weather Bureau station at Berry Field.

The U. S. Weather Bureau station at Berry Field makes measurements of temperature, relative humidity, and barometric pressure in the upper air using radiosondes. Balloons are released at 0600 and 1800 CST each day. Standard Weather Bureau equipment and procedures are used. Data are obtained from the surface to the elevation of the balloon at termination of the flight.

Solar, Sky, and Terrestrial Radiation

A recording actinometer (pyrheliograph)[42] was operated continuously on the roof of the Cordell Hull Building. The instrument provides a measure of intensity of direct solar and sky radiation. The duration of sunshine was measured continuously at the U. S. Weather Bureau station at Berry Field using a Marvin sunshine recorder.[43] From December 1958 to June 1959 continuous measurements were made of incoming solar and sky radiation and outgoing terrestrial radiation, the difference being net radiation. A recording economical net radiometer of the type described by Suomi[44, 45] was used.

Other Meteorological Measurements

Other meteorological measurements not described previously are those ordinarily made at U. S. Weather Bureau first order stations.[9] These are made routinely by the Bureau's station at Nashville Municipal Airport (Berry Field).

Special Nonroutine Studies

Sulfur Dioxide Emission Inventory

Contemplated studies of dispersion of pollutants in the atmosphere and other studies made it necessary to obtain a knowledge of sources of at least one pollutant. Sulfur dioxide was selected as most useful in this work because of the broad distribution of sources, the availability of data concerning characteristics of its sources, and because it was to be measured at a large number of stations.

The emission inventory was prepared on the basis of emission rates given in the literature; tabulations of the size, nature, and location of sources; fuel use data; engineering estimates of emissions from sizeable industrial sources; meteorological data (especially degree day values); questionnaires completed by industrial plants; and data concerning domestic fuel use obtained as a part of the morbidity survey. Data were tabulated for one mile square areas. Data for determining diurnal and seasonal variations were obtained. Height above ground of points of emission was obtained individually for major sources and estimates of average height of emission were made for multiple type sources such as chimneys of dwellings. The work was supervised by Dr. H. J. Paulus of the University of Minnesota.

Study of Dustfall Measurement Techniques

A study was made of several types of dustfall collectors for the purpose of evaluating variation in amount of dustfall collected by different types, variation in collection between a number of the same type collector at a given location, and desirability of collectors from the standpoint of ease of use. Further verification of previous work[46] was sought. Types of collectors used included simple polyethylene wastebaskets with and without added liquid; polyethylene wastebaskets with baffles, with and without added liquid; simple polyethylene collectors with thin, removable plastic liners; and a tall, slim cylindrical collector used in Canada.

Public Opinion of Air Pollution

An effort was made to determine public awareness of air pollution; opinion of what level of pollution is "too high"; what aspects of pollution people are concerned about and interested in; and what importance the public attaches to air pollution in relation to other problems confronting them. Opinions expressed by about 3000 people will be examined in the light of pollution levels and pollution sources influencing individuals and their socioeconomic status. These data were obtained as part of the morbidity survey.

Pollen Measurements

Atmospheric pollen concentrations were determined by use of flag samplers[47] operated at 10 stations in the aerometric network, from September through November 1958 and from March through June 1959. During the earlier time period volumetric samples of pollen were collected at station 60 and during the later time period at station 48 by drawing air through a membrane filter. Pollens were counted and identified at the University of Michigan under the direction of Dr. E. W. Hewson, under contract.

Pollution Level Forecasts

In order to test the possibility of predicting the pollution situation by meteorological methods, daily forecasts of pollution levels for the following day were made. Factors considered were wind speed and the difference between temperature at the surface and at the 900-millibar level, an index of stability. Forecasts indicated whether high, moderate, or low pollution levels were expected. The U. S. Weather Bureau station at Berry Field did this work during the period January 23 through July 1959.

Automobile Traffic Counts

A continuous count was made of automobiles passing in the street alongside station 60 for a period of four months. Recorded counts will be used in interpretation of results of continuous measurements of carbon monoxide at the same location.

Summary

The multiple objectives of this study were considered to be sub-objectives of two primary problems:

1. How to assess the atmospheric pollution of a community most accurately, with reference to both temporal variations and long-term averages, in relation to quantity, composition, and the factors affecting it, and;
2. How to assess the health effects that might result from this contamination as they varied in geographic and temporal distribution, recognizing that many other factors also might affect them.

These problems arose as the result of a relatively simple assumption: That health effects might vary consequent to exposure, both in time and geographically.

A very large study was therefore undertaken, primarily to ascertain whether proper measurements and experimental procedures could be designed to meet these objectives.

The present report describes the over-all study. Analysis of data is proceeding and as results of these analyses are obtained, they will be made generally available.

Note: Any mention of specific commercial products does not imply in any way endorsement of these products or recommendation of them over similar commercial products. Commercial names are given to reduce the need for descriptive material herein and to improve understanding of the work described.

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PROCEEDINGS of 1960 ANNUAL MEETING

AVAILABLE Through HEADQUARTERS

The ROLE *of the* PRIVATE CITIZEN *in* AIR POLLUTION *Control**

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Chairman, Cincinnati City Managers Committee on Automotive Exhausts

The participation of an educated citizenry in air pollution control is probably as important if not more important than in any other community problem for the following reasons:

a Air is ubiquitous; it is everywhere and at all times.
b Pure air is the thing we can do least without; man can live for weeks without food, for days without water, but only a few minutes without air.
c Air pollution is probably the hazard we are least prepared to combat as individuals; its control is a program in which we most need the co-operation of all citizens.

There are many steps the individual citizen can take to avoid the hazards of highway traffic, of water pollution, of disease, and of industrial activity. But there is little we can do solely as individuals, short of wearing a gas mask, to control the purity of the air we breathe. Concerted action as citizens is absolutely necessary.

What then are the roles an individual may assume to assert himself as a leader of his fellow citizens in supporting the air pollution control program. The several opportunities seem to be as follows:

1 Exhibit an exemplary attitude on air pollution control. Support the two basic philosophies that:

a Prevention avoids the need of cure.
b Dilution is no solution to pollution. (This jingle applies to air as well as to water.)

Let these two premises be our bywords in dealing with neighbors as well as with business and professional associates.

2 In business and industrial responsibilities we should encourage the training of staff personnel in pollution control cooperation. Make certain that new equipment and processes are protected to avoid release of contaminants; make efficient use of equipment already installed.

3 In professional societies and other community organizations, encourage and participate in programs leading to a better general understanding of pollution control problems. Give recognition to those who have done an outstanding job in solving pollution control problems.

4 Serve on citizens committees, pollution control boards, and other volunteer groups supporting the program.

5 Support the adoption and enforcement of appropriate ordinances in our communities.

The principal illustrations I have to present in this paper are in the area of professional society activity and in the area of service on community committees.

Professional Society Activity

The Engineering Society of Cincinnati maintains a Civic Affairs Committee which gives attention to various community problems. At least once a year air pollution control is given the spotlight.

Each year the Society supports the Cleaner Air Week program and as a part of this activity co-sponsors with the City of Cincinnati Air Pollution Control Bureau the annual Ohio Valley Air Pollution Control Conference.

Last year the October meeting of the Society was given over to a complete program on the theme: "Evaluating the Progress Toward Cleaner, Healthier Outdoor Air," in conjunction with the Ohio Valley Conference.

An Award Program

Awards were presented for outstanding industrial control in four classifications: *1* combustion equipment, *2* dust and fume prevention, *3* odor control, and *4* waste disposal. One winner and two runners-up were honored with certificate presentations by the city manager at the Society dinner meeting.

The manner in which air pollution control touches on a variety of enterprises is indicated strikingly by the list of nominees:

Burger Brewing Co.	Barrett Division
Sawbrook Steel Casting Co.	Davison Chemical Co.
Procter and Gamble Co.	Carlisle Chemical Co.
Cincinnati Gas and Electric Co.	Esco Coffee Co.
Washington Park School	City of Wyoming
Cincinnati City Hall	University of Cincinnati

This award plan was well received. Attendant publicity was featured in the local press and in the "Engineer and Scientist" weekly publication circulated to 6500 members of the 23 affiliated technical societies in Cincinnati.

An interesting suggestion has been made for future programs. It is that the spotlight might also be turned on the most difficult periods in Air Pollution Control even as the National Safety Council makes an object lesson of the highway accident rate on conspicuous holiday weekends. Why not identify the "dirtiest" month, week, day, and hour of the year? From the point of view of the "Soiling Index" this was in Cincinnati in November during the week of 9 to 15, with a peak on Monday the ninth between 6:00 AM and noon. What was it in your town?

Uniform Ordinance Citizens Committee

A highly successful citizens committee in Cincinnati recently was one which drafted a "Uniform Ordinance for Air Pollution Control." This model ordinance was designed to be used by the communities bordering Cincinnati which are too small to have their own pollution control departments but which use the contract services of the City of Cincinnati in the Metropolitan Air Pollution Control Program.

In less than a year, five contiguous communities voted the model ordinance into law and agreed to support a common hearing board which is now in operation. This board already has had its initial meeting to rule on an appeal

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

and a satisfactory agreement was reached at the first hearing.

Significant also was the fact that this first "case" was the result of a complaint from one community concerning an offender in an adjoining community—a clear illustration that Air Pollution Control is an inter-community problem. Pure air for us as citizens of any geographic area will be achieved only when we can raise our sights of co-operative activity to transcend the artificial horizons of political boundaries.

The concept of a uniform ordinance for air pollution control seems to have been a highly successful and well-received plan in metropolitan Cincinnati.

Citizens Committee on Automotive Exhausts

Another continuing citizen's activity in Cincinnati since 1956 is that of the City Manager's Committee on Air Pollution from Automotive Exhausts.

Last year, a member of City Council requested the City Manager to investigate and report upon the advisability of enactment of legislation governing the inclusion of additives in gasoline. After a thorough search into the many aspects of this complex problem, the committee recommended as follows:

A. Gasoline Additives: Based on information available at this time, it would not be advisable for the City of Cincinnati to consider legislation regulating the use of gasoline additives.

B. Automotive Engine Exhaust: The city should gather and maintain full information concerning the general development in the field of air pollution from automotive exhausts. The city should also take steps to obtain information as to the nature and extent of the problem in Cincinnati. The implementation of these recommendations would seem to require some or all of the following measures.

1. To continue an advisory Committee on Automotive Engine Exhausts.
2. To develop and maintain a moderate and economical program, through appropriate local agencies, of sampling and analysis of specific constituents of the atmosphere derived from automotive exhausts.
3. To recognize that the availability and excellence of the Cincinnati Safety Lane provides an unparalleled opportunity for Cincinnati to pioneer means of using its inspection system in correcting those forms of improper maintenance and adjustment that contribute to air pollution.
4. To be prepared to take appropriate action should satisfactory devices for the reduction of the air pollutants from automotive exhaust be made available and their use become necessary.

The report was transmitted to the City Manager on August 5, 1959, and in turn to the City Council on September 2, 1959. The Advisory Committee remains on call.

Concurrently the Academy of Medicine Committee on Preventive Medicine published a report in the Cincinnati Journal of Medicine, April 1959. This report urged the establishment of a control and monitoring program dealing with such items as sulfur gases and total oxidants or ozone. It also recommended that consideration be given to the establishment of standard levels of concentration of recognized pollutants, the presence of which would be indicative of the approach of danger to the public health.

A step toward this objective was taken by including in the 1960 city budget a request of the Air Pollution Control Bureau, for a program of continuous monitoring of three specific gaseous pollutants: (*1*) sulfur dioxide, (*2*) oxidants or ozone, and (*3*) carbon monoxide. However, City Council withdrew financial support for this program from the appropriation ordinance and it cannot be undertaken at this time.

Air Pollution Control League

The long-time interest of citizens in Cincinnati in the air pollution problem is well demonstrated by the Air Pollution Control League which recently issued its 54th Annual Report. This organization, founded in 1906 as the Smoke Abatement League, is a member of the Community Chest group. It has a full-time executive secretary and an outstanding board of trustees.

Air Pollution Control Bureau

All of these citizen activities are in support of the Air Pollution Control Bureau of the City of Cincinnati, which comprises a staff of 24 authorized personnel. The Bureau has a current operating budget of approximately $150,000. Its head reports directly to the Director of Safety who in turn reports directly to the City Manager.

It seems of utmost importance to have the Air Pollution Control Bureau well-identified as a top level almost autonomous agency in the City government. Air pollution control should receive high priority attention.

A Challenge

Perhaps the greatest challenge we have as citizens is to see that a City Council or other legislative body is not stampeded by an alarmist into passing legislation, as for automotive engine exhaust control, without adequate technical data about the offending pollutants.

It is unfortunate but true that it is sometimes easier to work up enthusiasm for "passing a law" than it is to work up similar enthusiasm in support of an appropriation for much-needed monitoring equipment. Only through a quantitative record of the quality of our air and trends in its pollution will we be able to make intelligent decisions concerning its control.

It is important that we start monitoring programs now throughout the country. In the words of Charles W. Gruber, Cincinnati Air Pollution Control Engineer:

> "Tomorrow no one can determine what was in the air today. Measurement by instruments is the only procedure which will record today's pollution for tomorrow's decisions."

Certainly none of us want ever to come to a stage where the daily meteorological reports including temperature, wind, humidity, and river stage will need to be accompanied in our own communities by detailed reports on air pollution. Where this already is being done, we want to work toward making it no longer necessary. We may avoid the spread of need for such warning reports only if we start now scientifically to make a reliable record of air quality.

Cincinnati citizens take the matter of Air Pollution Control support as serious business. We hope that you receive similar citizen support in your communities.

EXHAUST PROBLEMS TACKLED BY BOARD

At the March meeting of the California Motor Vehicle Pollution Control Board, the first steps were taken by the Board to control emissions from crankcases as well as emissions from exhausts. Since this is a less complicated problem, it is anticipated that devices can be certified and the law may become effective for this category of emissions in the near future.

At the April meeting of the Board test procedures were approved for evaluating crankcase emission devices and the first steps were taken to formally adopt the criteria with which such devices must comply in order to receive a certificate of approval from the Board.

Testing of these devices will be largely the responsibility of the manufacturers with supervision and evaluation by one member of the Board's engineering staff.

A goal of approval of the first device has been set for July of this year. Estimates as to the importance of hydrocarbons emitted from the crankcase vary, but there is general consensus that this is an important contributor to air pollution and its early control is heralded as an important forward step in the control of emissions from automobiles.

The exhaust control device situation does not promise any such speedy solution.

NEW PRESIDENT AND BOARD CHOSEN

APCA announces the 1961–62 Board of Directors and President of the Association.

Dr. W. L. Faith, managing director of the Air Pollution Foundation until its liquidation, has opened a consulting chemical engineering office in San Marino, California, where his specialty is the evaluation of research and development programs, particularly in the chemical and food industries, industrial air pollution control programs, and community and governmental relations.

Dr. Faith joined the Air Pollution Foundation in March 1954 as chief engineer and deputy director. He became managing director in 1956.

Prior to this, he was director of engineering for Corn Products Refining Company, Argo, Illinois (1945 to 54); consultant and deputy director, Office of Production Research and Development, War Production Board, Washington, D. C. (1942 to 45); and professor of chemical engineering, Kansas State College, Manhattan, Kansas (1933 to 42).

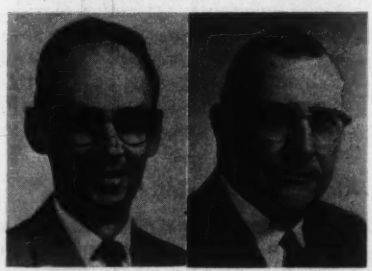
He is a member and former director of the American Institute of Chemical Engineers, a member of the American Chemical Society, and a diplomat of the American Academy of Sanitary Engineers.

S. S. Griswold C. W. Gruber

S. Smith Griswold, Board of Directors, is an Air Pollution Control Officer of the Los Angeles Air Pollution Control District. He holds a B.A. and M.A. in governmental administration from Stanford University. He has been with the Los Angeles Division of Administrative Research; served as Budget Director of Los Angeles County; and was a captain in the U. S. Navy Ready Reserve. Mr. Griswold was a member of the National Advisory Committee on Community Air Pollution, California Advisory Committee on Air Sanitation.

* * *

Charles W. Gruber, Board of Directors, serves as an Air Pollution Control and Heating Engineer, City of Cincinnati, Ohio. He is a graduate mechanical engineer of the University of Cincinnati and a registered professional engineer of the State of Ohio. Among his many achievements, Mr. Gruber has been in charge of the Air Pollution Control Program and Safety Inspection of Heating and Combustion Equipment for the City of Cincinnati since 1938, past president of APCA, past chairman of the East-Central Section, member of the National Advisory Committee on Community Air Pollution, served with U. S. Public Health Service, a member of ASME and Engineering Society of Cincinnati, and Chief, Atomic, Biological and Chemical Services Division of Ohio Valley Civil Defense Authority.

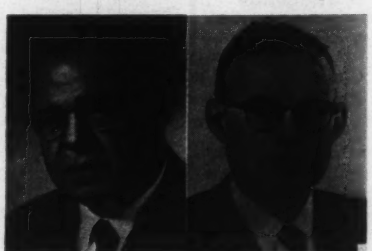


E. R. Hendrickson J. McAfee

E. R. Hendrickson, Board of Directors, is Professor of Sanitary Engineering at the University of Florida, as well as chairman, Florida APC Commission. A graduate of Penn State, Dr. Hendrickson earned an M.S. and Ph.D. at the University of Wisconsin. He has served with the U. S. Army Corps of Engineers; as Consulting Sanitary Engineer in Caracus, Venezuela; and instructor at the University of Wisconsin. At present he is chairman of APCA's newly formed Education and Training Committee.

* * *

Jerry McAfee, Board of Directors, Vice President-Executive Technical Advisor of Gulf Oil Corporation, Pittsburgh, Pennsylvania, is a graduate of the University of Texas, B.S., chemical engineering, and M.I.T., Sc.D. Mr. McAfee has been associated with Universal Oil Products Company in Chicago until he went with the Gulf Oil Corp.



L. M. Roberts R. L. Stockman

Lawrence M. Roberts, Board of Directors, is at present Senior Vice President and consultant of Research-Cottrell, Inc. at Bound Brook, New Jersey. He received his B.S. in chemical engineering at Penn State and has been employed with Research-Cottrell since 1929. He is a nationally known authority on industrial gas cleaning and air pollution control. Mr. Roberts is a Director of Research-Cottrell, Inc. and Research-Cottrell (Canada) Ltd.

* * *

Robert L. Stockman, Board of Directors, is Engineer in Charge, Air Sanitation and Radiation Control Section, Department of Health, State of Washington. He has a B.S. in civil engineering from Oregon State College. Mr. Stockman has been with the Washington State Department of Health since 1941, with the exception of three years military service and two years private practice. He served on the membership and nominating committees of APCA, was Contributing Editor for the West Coast Section, and Chairman, Air Pollution Committee, Pacific Northwest Sewage and Industrial Wastes Assoc.

J. H. Strassburger A. J. Benline

Julius H. Strassburger, Board of Engineers, is Vice President, Research and Development, National Steel Corporation, Weirton, West Virginia. A graduate of Stevens Institute of Technology, he was an instructor there in chemistry until he went with Bethlehem Steel Company. Two years later he became associated with the Weirton Steel Company, serving in various capacities until his present position with National Steel Corporation. He is noted for development of oxygen use in industry.

* * *

Arthur J. Benline, Board of Directors, is Commissioner, Department of Air Pollution Control, New York City. He holds a Bachelor's degree in engineering from New York University. He has held various posts concerning designing and installing theater air conditioning and sound systems in New York City; was Superintendent of Housing and Building Department; served as a captain in the U. S. Navy; and was Director of New York State Building Construction Code.

JOHN WOOD COMPANY OFFERS BOOKLET ON AIR POLLUTION

"Together We Can Check the Blight of Air Pollution," a 20-page booklet produced by the John Wood Company's Air Pollution Control Division (Florham Park, New Jersey), indicates that we may be headed for more control over our daily lives by the federal government, particularly in view of President Kennedy's recent statement that "We need an effective Federal air pollution control program now."

The booklet points out that Federal control is unrealistic; that control logically belongs, and should remain, at the local level. It also stresses that a workable partnership between the government and industry is both feasible and desirable, and would effectively support local control authority.

Experts agree that each community has individual air pollution problems. Though a community may have some pollution sources basically similar to those a thousand miles away, its meteorology and topography may differ widely. Consequently, authority to handle local problems should be in local hands. At the same time, the local community, no matter how small, should be able to draw on the wealth of talent and experience available from existing air pollution control activities across the country. Unfortunately, this is not possible today, because proper co-ordination is lacking.

In taking a stand on this problem, the John Wood Company does not merely take exception to proposed and existing air pollution control activities. Instead, the company points out that even though industry is indicated as the cause of almost all significant pollution emissions, more than half are from other sources. More important, industry cannot continue to spend money at continuously accelerated rates for costly, nonproductive air pollution control equipment, as well as related research and development projects.

Reviewing the multitudinous air pollution control activities of Federal agencies, industry, industrial associations and technical societies shows the obvious duplication of effort and needless expense. On the other hand, the booklet highlights the Air Pollution Control Association's reservoir of scientific knowhow, which represents a vast untapped potential for a co-ordinated, effective approach to air pollution abatement.

Specific needs, and concrete proposals for remedial action are spelled out:

Public Health

The need: Definitely prove or disprove the effects of polluted air on public health.

The proposal: Have the U. S. Public Health Service concentrate on medical research, a field in which it is eminently qualified. Leave other air pollution control activities such as technical services, research, and development projects to those most qualified to deal with them.

Fiscal Legislation

The need: Establish a realistic fiscal policy in which both government and industry can participate.

The proposal: (*1*) Enact legislation permitting industry to treat expenditures for air pollution control equipment as current operating costs. (*2*) Loans should be provided by the federal government to small businesses, otherwise unable to meet a heavy initial investment in air pollution control equipment, such loans to be paid back over a period of years. (*3*) Research funds should be made available by the federal government for industry to develop and test air pollution control methods.

Education

The need: Provide personnel specifically trained in the science of air pollution abatement.

The proposal: Set up a scholarship program, with government and industry participating, calling for selected individuals with a Bachelor of Science Degree to be sent to several schools in succession. Courses should include meteorology, medicine, agriculture, etc., all necessary to understand air pollution problems. Completion of the program should lead to a Master of Science Degree.

The ever-increasing complexity of air pollution control requires the fullest use of engineering and scientific talent, and a cadre of engineers trained to cope with atmospheric pollution from all sources: government, industry, and public activities. It is also proposed that federal government engineers, obtaining advanced degrees with federal financial aid, should be required to take an air pollution orientation course.

Co-ordination

The need: Co-ordinate air pollution abatement activities on the national level, yet maintain control at the local level.

The proposal: Use the existing, nonprofit Air Pollution Control Association as a nucleus for co-ordinated activity.

The Association, whose membership includes authorities in all the fields of science relating to air pollution, can serve as a national clearing house, and should be recognized as such by the federal government. It can provide

(*Continued on p. 302*)

RILEY STOKER CONTRACTS FOR DUST COLLECTORS

One of the largest mechanical dust collector contracts in several years was placed recently with the Western Precipitation Division of Joy Manufacturing Company in Los Angeles by the Riley Stoker Company for the Arizona Public Service Company's Four Corners Power Plant near Fruitland, New Mexico.

Eight dust collectors of the Multiclone type are to be installed to collect fly ash from two Riley Stoker pulverized coal fired boilers. The Multiclones will handle a total of over 1,000,000 cubic feet of flue gas per minute.

Inlet Design of Interest

Of special interest is the top inlet design which permits the introduction of the dust laden gases through the top of the collector from a vertical direction—rather than through the normal type of horizontal introduction. This design is unique in appearance but is fully as efficient as the standard type.

Another feature of the installation is the use of specially designed hoppers to handle the unusually large amount of fly ash to be recovered from the flue gas according to Ed Lawlor, Product Sales Manager for Western Precipitation.

Five Groups Chosen For Special Research

The American Petroleum Institute has selected five organizations to work on the principal projects of a special oil burner research program, to be started in the very near future.

The names of the research groups, and the projects on which they will work, are: Armour Research Foundation, Chicago, Illinois: air-fuel mixing and recirculation; Arthur D. Little, Inc., Cambridge, Massachusetts: new means for fuel atomization; Atlantic Research Corporation, Alexandria, Virginia: ways to minimize deposits during vaporization of No. 2 heating oil; Battelle Memorial Institute, Columbus, Ohio: more suitable ignition systems, air compressors, and fuel pumps for small oil burners; Stanford Research Institute, Menlo Park, California: the effects of spray-droplet size on combustion.

The purpose of the research program is to develop, interpret, and disseminate new technical information that will assist equipment manufacturers in producing improved equipment using distillate fuel. All research findings will be dedicated to public use.

PHS PREPARES GUIDE BOOK FOR URBAN HEALTH PROBLEMS

The broad fields of environmental concern within the nation's metropolitan areas—air, water, food, and shelter—present new, changing, and challenging health risks. The interplay of these factors is not fully understood. On the other hand, there is much "know how" that just isn't being applied, according to Wesley E. Gilbertson, Chief of the Division of Engineering Services, Public Health Service.

Public Health Service engineers, probing environmental health problems in a dozen metropolitan areas during the past three years, have found a large gap between technical competence in developing sanitary facilities and the ability to use this competence efficiently in the face of upsurging needs, he said.

As a result of these studies, the Public Health Service has prepared an "Environmental Health Planning Guide" to provide local communities with guidelines for collecting and analyzing facts on health-related services and facilities within an expanding urban area. The *Guide* shows how to apply these factors to zoning, land use, subdivision regulations, recreation facilities, and community redevelopment, emphasizing planning for future community needs and growth, Gilbertson added.

"Cities can't push a problem outside the city limits—and have it remain outside for long. Often there isn't a city limit any more. The stream that pollutes the city, pollutes the county, the state, and perhaps the next state as well."

Speaking at the first National Conference on Environmental Engineering and Metropolitan Planning held at Northwestern University, Mr. Gilbertson said cities can't be expected to solve these problems entirely by themselves. They are already hemmed in by the magnitude of local issues, by spiralling costs of doing business, and backed up against the reality of no really new large sources of income. And state governments can't be expected to—and certainly won't—assume all the problems of the cities.

Using the new PHS "Environmental Health Planning Guide," a local civic organization in Fort Wayne, Indiana, has spearheaded an area-wide study and evaluation of environmental health problems, mobilizing voluntary and official groups into a united effort, Mr. Gilbertson reported. Another approach was used in Omaha, Nebraska, where planning, public works, health, and other agencies collaborated as a team to prepare an evaluation of their area.

"Somehow, better bridges need to be built between government and the people," he said. "Voters have turned down desirable proposals, not on principle or cost, but because of a lack of understanding, protest, or angry reaction against a lost voice in community affairs." The approaches used in Fort Wayne and Omaha have aroused considerable public interest in, and support for, the survey results.

Stimulation and encouragement of collaboration between health and planning groups within a community or metropolitan area is one of the most important missions of the PHS.

The articles, "Air Pollution and Health: General Description of a Study in Nashville, Tennessee," by L. D. Ludley, et al., and "Sampling Stations and Time Requirements for Urban Air Pollution Surveys," by D. M. Keagy, et al., represent the first of a series of reports which describe and evaluate a comprehensive aerometric and health effects study conducted by the U. S. Public Health Service and Vanderbilt University in Nashville, Tennessee. They will be published in June and July, respectively. The first report of the series presents a general description of the study and outlines the medical and engineering objectives. The second report presents some of the results obtained during the study. Further results will be reported in future issues of the JOURNAL.

Booklet Published

(*Continued from p. 301*)

guidance and counsel to the Secretary for Urban Affairs, as well as state and local levels. Such help would be particularly valuable to the small community, where now the control authority must depend upon his own limited resources and knowledge.

The first copy of this booklet was delivered to the White House on Thursday, April 6. Copies were mailed to all members of Congress, governors of all states, and to mayors of principal cities. Copies also were mailed to leading educators, industrialists, and medical men.

The booklet does not presume to solve all air pollution problems. However, the John Wood Company sincerely believes that industry and government, working together on a partnership basis and following the thinking expressed in the proposals, can effectively check the blight of air pollution. It is hoped that "Together We Can Check the Blight of Air Pollution" will stimulate thinking and provoke vigorous leadership and action which is needed now.

For copies of the booklet, write to APCA headquarters.

CALENDAR

June 25–30	Summer Engineering Seminar on Electrical Precipitation, Pennsylvania State University, University Park, Pennsylvania.
September 21–22	East Central Section Annual Technical Meeting, Louisville Kentucky.
October 16–17	International Conference on Ionization of the Air, The Franklin Institute, Philadelphia, Pennsylvania.

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NEWS FROM THE CONTROL DISTRICTS

New York City

New Yorkers were urged by Arthur J. Benline, Commissioner of the New York City Department of Air Pollution Control, to keep their automobiles in good repair, in order to reduce air pollution and to cut operating costs.

"Again in 1960, pollution from automotive vehicles increased, while most other pollution decreased or remained stationary at relatively low levels," Commissioner Benline said. "There is still no device which can effectively control exhaust pollution, although crankcase pollution, which constitutes about 30% of the total pollution from an automotive vehicle, is capable of being controlled. Much can be done to reduce automotive pollution by proper and consistent maintenance and this has the added benefit of reducing the cost of gasoline, oil, and repairs."

Record Number Complaints

A record number of complaints were answered and a record number of violation notices were served by the New York City Department of Air Pollution Control during the first three months of 1961, it was announced today by Arthur J. Benline, Commissioner. The enforcement statistics released cover the quarter from January through March.

The figures for January through March 1961, are as follows: complaints received, 3831; violation notices issued, 1678; summonses served, 216; fines levied in Municipal Term Court, $4550; office hearings held with violators, nine; smoke alarms ordered, 255. The figures for January through March 1960, are as follows: complaints, 3707; violation notices, 1510; summonses, 150; fines, $3890; hearings, 42; smoke alarms ordered, 233.

Commenting on the figures, Commissioner Benline said: "Although complaints are at an all time high for a three-month period, a similar pattern was set last year, when the final figures showed an approximate 10% decrease in complaints for the 12-month period.

Bay Area

Los Angeles County could be as free of smog by 1965 as it was in 1940.

This is the conclusion reached by the Air Pollution Control District in a 290 page report submitted to the Board of Supervisors by Air Pollution Control Officer Smith Griswold.

Second of a series of Technical Progress Reports being published by the District, the volume "Air Quality of Los Angeles County," sums up 10 years of air measurement and analysis by the APCD.

Smog Reduction Facts

The prediction that smog may be reduced to its pre-war level by 1965 is based upon these facts, the report states:

1 Many contaminants from nonmoving sources already have been reduced below the 1940 level.

2 The other contaminants of significance from nonmoving sources should be reduced to that point by developments already under way or planned for the next few years.

3 Effective air pollution controls for motor vehicles are scheduled to be on most vehicles by 1965.

After 1965 a continuing effort will be needed to restrain pollution as industry, population, and motor vehicles continue to increase and expand into areas now undeveloped.

During the past 20 years, population and motor vehicles have more than doubled, gasoline consumption has more than tripled, and other factors affecting air pollution have increased.

Similar increases after 1965 could cancel out the gains made in controlling smog unless control techniques can be improved further.

Smog effects during the past 10 years were at their worst during late 1955 and through 1956, is shown in the report by summaries of measurements of air contaminants and their effects. A reduction in smog effects is noted during 1957–58.

Bay Area oil refineries will spend about an additional $8 to $10 million by the end of 1962 to bring their operations into full compliance with anti-industrial smog Regulation 2.

WILLIAM T. INGRAM

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In Memoriam...

Bernard Wich, Village Engineer, Herkimer, New York, passed away March 30, 1961.

LEAD CONTENT

(*Continued from p. 288*)

Relationship Between Sulfur Dioxide and Particulate Matter in the Atmosphere," *Am. Ind. Hyg. Assoc. J.* 19:371 (1958).

8. Dept. of Urban Renewal, Cincinnati, Ohio, 13th Annual Report, "Residential Building Permits Issued in the Cincinnati Metropolitan Area" (February 1, 1960).
9. Cincinnati Real Estate Board, "Number of Housing Units Erected in Hamilton County," compiled by Harry J. Mohlman, Sec.
10. George J. Hennekes, "Area Data of Hamilton County" (1958).
11. D. A. Hirschler, L. F. Gilbert, F. W. Lamb, and L. M. Niebylski, "Particulate Lead Compounds in Automobile Exhaust Gas," *Ind. Eng. Chem.* 49: 1131 (1957).

AP AND ELECTRICITY

(*Continued from p. 269*)

are visible and other sensory evidences traceable to us. Basically, I have no great objection to those who are criticizing us for the conditions they experience. I also cannot complain too bitterly about those who object that we have not used the most effective measures in the past, even though these criticisms, based on hindsight, are often quite unfair. However, when people criticize my company and my industry, claiming that we have not tried, and are not trying, to do a good job in air pollution control—well I say that just isn't so.

Welcome New Members

(*Continued from p. 261*)

Reilly, William
Philadelphia, Pa.

Sax, Edward A.
Cambridge, Mass.

Schaefer, J. W.
Los Angeles, Calif.

Schillmoller, C. M.
Los Angeles, Calif.

Schmidt, Walter A.
Los Angeles, Calif.

Smrcka, A. K. J.
Dorion, Quebec, Canada

Sojka, Boris
Palo Alto, Calif.

Spencer, John C.
San Francisco, Calif.

Sprague, Percy B.
Valley Stream, N. Y.

Sullivan, Bernard E.
Seattle, Wash.

Watt, Robert Denny
Seattle, Wash.

Welsh, Gene B.
Silver Spring, Md.

Wiseman, Marrs
Charleston, W. Va.

Ziegfeld, Robert L.
New York, N. Y.

Personalia

Dr. Henry C. Wohlers has assumed the position of Director of Technical Services for the Bay Area Air Pollution Control District. He replaces John Yocom. Dr. Wohlers, an Air Pollution Senior Analytical Chemist with Stanford Research Institute since 1949, has done considerable work on photochemical smog and fluoride air pollution.

* * *

Dr. Leslie Silverman was recently appointed head of the Department of Industrial Hygiene at the Harvard School of Public Health. Dr. Silverman, a Professor of Engineering in Environmental Hygiene, is known for his basic and applied research on control measures for industrial air pollution. He is director of the radiological hygiene program of the School of Public Health and a member and former chairman of the Atomic Energy Commission's advisory committee on reactor safeguards. He succeeds Professor Philip Drinker, who becomes Professor of Industrial Hygiene emeritus in August.

* * *

Kenneth Kowald is now engaged in the practice of law in Jamaica, New York.

* * *

Frank R. Milliken has been elected president of the Kennecott Copper Corporation. Mr. Milliken formerly was executive vice president of Kennecott, having assumed that position in 1958. Between 1952 and 1958 he served as vice president in charge of Kennecott's mining operations. Kennecott Copper Corporation is a sustaining member of APCA.

* * *

William G. Henke, Frank H. Ford, and **John W. Homer** have been appointed to managerial posts in sales and marketing with Research-Cottrell, Inc. Mr. Henke was named Manager, Sales Co-ordination. His most recent experience has been as a district representative. Mr. Ford assumes the newly created post of Marketing Manager and Mr. Homer became District Sales Manager of Research-Cottrell's New York office.

* * *

Dr. John F. G. Hicks has been named associate director of Battelle Memorial Institute, Dr. B. D. Thomas, president, announced.

Formerly vice president of the Corning Glass Works and vice president and technical director of Corning Glass International, Dr. Hicks is a chemist with broad experience.

CINCINNATI U. OFFERS GRADUATE PROGRAM IN INDUSTRIAL HEALTH

Problems of chronic disease and occupational hazards will be studied in a specialized graduate training program being offered for the first time in the nation by the Institute of Industrial Health, University of Cincinnati. The institute is an activity of the Kettering Laboratory in UC's College of Medicine.

Dr. John J. Phair, professor and director of the University's division of preventive medicine, announced the graduate program is being initiated immediately. It is open to physicians and qualified nonmedical personnel.

The Public Health Service has granted $135,000 to support the program for a four-and-a-half-year period.

This is one part of the PHS's overall program to increase and broaden the teaching of epidemiology and biostatistics, but UC's project is believed to be the only one in the nation to concentrate primarily on occupational hazards, Dr. Phair said.

UC's Institute of Industrial Health is a national center for research and training in occupational medicine and environmental health, which includes such areas as industrial hygiene, air pollution, sanitary engineering, and toxicology.

In addition, the University has access to the wide experience of the staff of the U. S. Robert A. Taft Sanitary Engineering Center and the Occupational Health Field Headquarters here.

The new program will lead to either a master or doctor of science degree. It will include the basic courses of biology and toxicology but the emphasis will be on epidemiological investigations as well as biostatistical and mathematical applications in the solution of industrial problems.

Those interested can apply to the University's Institute of Industrial Health.

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Dr. Leighton, H. Pier Honored at Meeting

Dr. Philip A. Leighton and Harry M. Pier were honored by APCA at its recent Annual Meeting.

Dr. Leighton is the recipient of the Frank A. Chambers Award in recognition of his achievements as a teacher and a scientist, and especially for his contribution to the basic knowledge of the photochemistry of polluted atmospheres.

Dr. Leighton

As a consultant for the Air Pollution Foundation he carried out studies that culminated in the publication of two reports: "Solar Radiation, Absorption Rates, and Photochemical Primary Processes in Urban Air" and "Photochemical Secondary Reactions in Urban Air." These reports were a pioneering study of the application of photochemical principles to the urban air pollution problem and are used as a basic guide in the fields of air pollution chemical research, and control of photochemical smog.

* * *

Mr. Pier has been named honorary member of the Association. Before his retirement he served with Research-Cottrell, Inc. as general sales manager and later as special assistant to the chairman of the board for air pollution control activities. He is a past member of the Board of Directors of APCA and past Executive Secretary.

H. M. Pier

APCA extends its congratulations to these two gentlemen and thanks them for their contributions to the Association.

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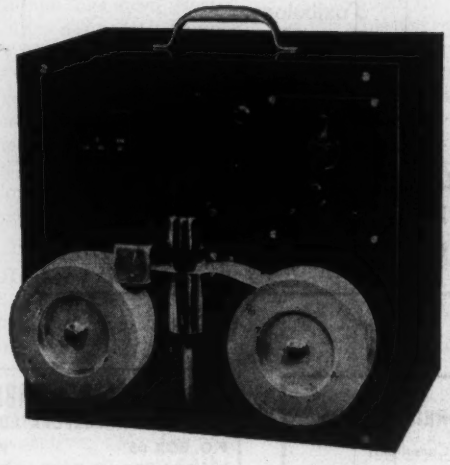
* * *



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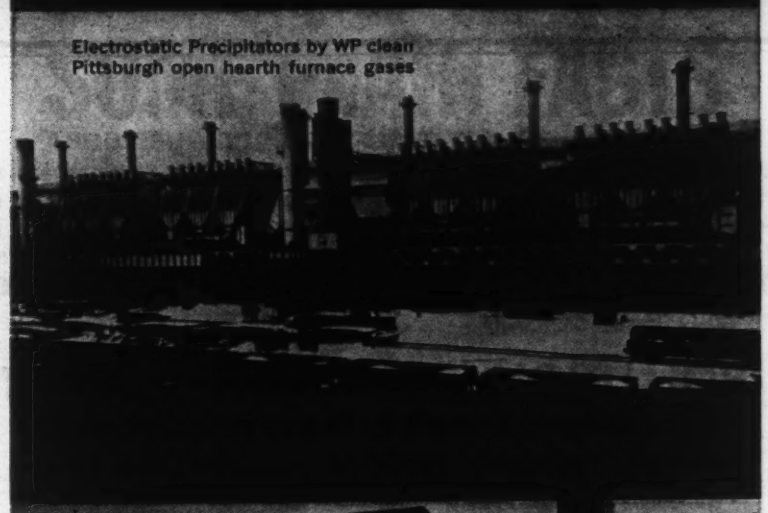

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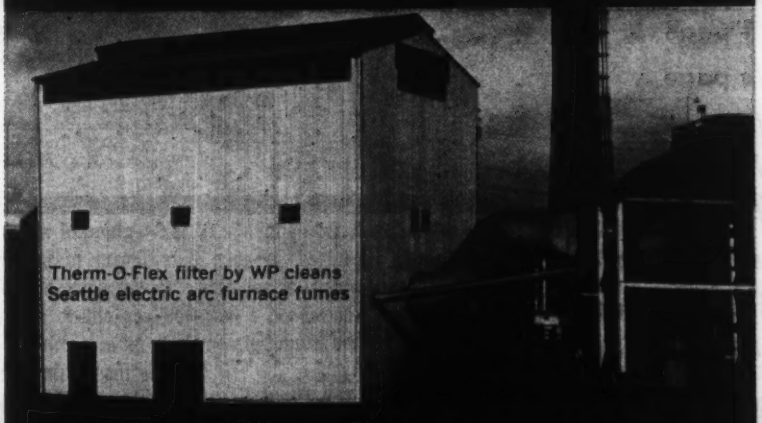

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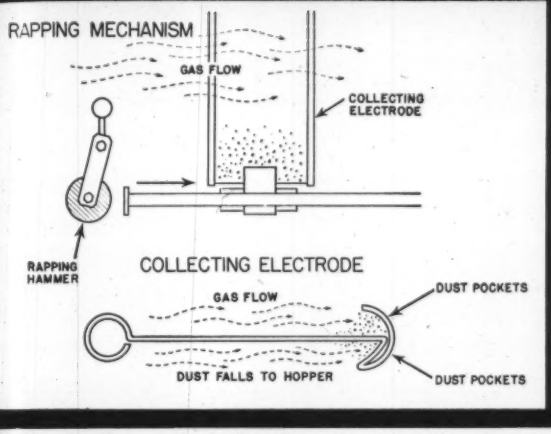
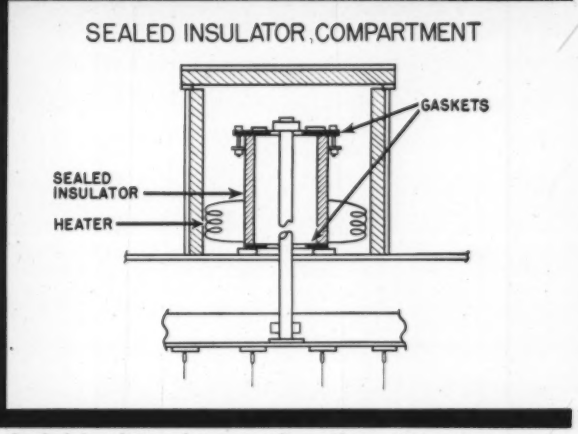
ABOUT SUPERIOR PRECIPITATOR PERFORMANCE

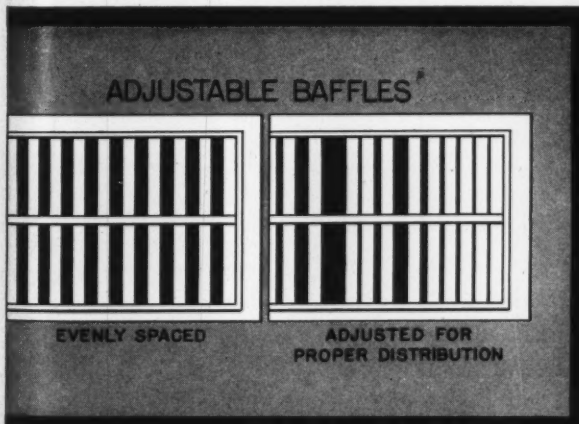
Buell Precipitators are designed and constructed for rugged service and superior performance. Frills and internal frim-fram of a doubtful value are eliminated in favor of strength and simplicity. The casing, outside supports, and internal parts are of rugged construction; and the four-point suspension of emitting electrodes ensures the greatest stability. Here are just a few of the outstanding features of Buell Precipitators.

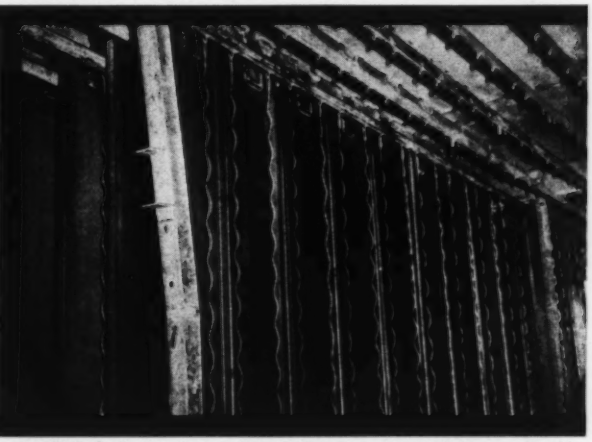




Effective Continuous Cycle Rapping—Yes, it's mechanical. A simple, rugged system free of complicated gadgets; assures positive dust shearing action. Each row of electrodes is rapped separately—in the direction of the gas flow—on a continuous cycle. Dust is sheared off, drops in an agglomerated mass and pockets on electrodes minimize reentrainment.

Sealed Insulators Improves Operation—High voltage quartz support insulators are completely sealed; prevents gas and dust leaking into insulator compartment and outside air leaking into precipitator. There is no need for costly ventilating systems. Thermostatically controlled electric heaters insure start-up without danger of moisture condensation and insulator breakdown.





Uniform Distribution of Gas Flow—Field adjustment capability is vital. Buell's adjustable baffle permits final positioning after field measurement of actual flow distribution . . . because gas flow patterns are not entirely predictable. The Buell distribution system assures equal gas loading through the precipitator; eliminates ineffective "dead" areas around passages and prevents "sneak-by."

Buell Spiralectrodes cut maintenance to a minimum. Buell's record stands at less than 1% replacement in this key area. Self-tensioned spiralectrodes eliminate vibration and "off-center" swaying, often prevalent with weight-tensioned wires. They're structurally fixed and once installed stay in alignment. The spiralectrode provides greater emission than straight wires.

Buell precipitators are simple and effective. They're designed for continuous service. You'll be glad you turned to Buell when you experience superior performance and low maintenance. Detailed literature describing all features is available.

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The Buell Engineering Co., Inc., Dept. 51-F, 123 William Street, New York 38, N. Y. Northern Blower Division, 6438 Barberton Avenue., Cleveland, Ohio.
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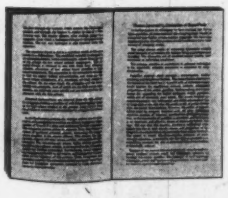
Catalytic's systems draw fumes from processing equipment, and pass the fumes through a circulating fan, discharging them through the catalyst element. With the catalytic system, "flameless" combustion takes place, and the heat needed is only 500° to 650° F., depending on the fume concentration. The resulting odor-free, color-free gases are then available for heat recovery, re-use in the processing equipment, or discharge to stack.

BTU's are valuable. Many fume streams have high potential fuel energy. In some processing applications, the recovery of this BTU value in dollars will pay for the equipment in a matter of months. Values too, in plant safety, employee morale, healthful, more pleasant working conditions, and improved community good-will can be measured in benefits to the firm employing truly effective fume and odor elimination.

Catalytic Combustion elements are built to standard sizes and complete systems are custom engineered to maximum effectiveness.



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